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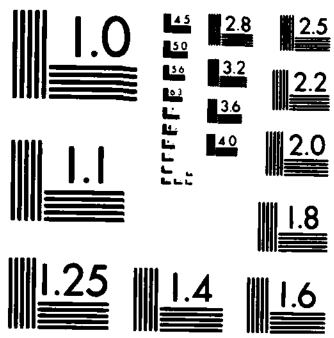

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NASA Contractor Report 3967

System Life and Reliability Modeling for Helicopter Transmissions

M. Savage and C. K. Brikmanis

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System Life and Reliability Modeling for Helicopter Transmissions

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SUMMARY

A computer program which simulates life and reliability of helicopter transmissions is presented. The helicopter transmissions may be composed of spiral bevel gear units and planetary gear units - alone, in series or in parallel. The spiral bevel gear units may have either single or dual input pinions, which are identical. The planetary gear units may be stepped or unstepped and the number of planet gears carried by the planet arm may be varied. The reliability analysis used in the program is based on the Weibull distribution lives of the transmission components. The computer calculates the system lives and dynamic capacities of the transmission components and the transmission. The system life is defined as the life of the component or transmission at an output torque at which the probability of survival is ninety percent. The dynamic capacity of a component or transmission is defined as the output torque which can be applied for one million output shaft cycles for a probability of survival of ninety percent. A complete summary of the life and dynamic capacity results is produced by the program.

INTRODUCTION

In the helicopter industry, experimental testing programs are used to measure the relative merits of different transmissions [1,2,3]. These tests are costly in terms of time and resources. The tests should be complemented with computer simulations of many possible designs, so that only optimal designs are brought forward to the testing stage in helicopter transmission development.

This report describes a computer simulation program which models the life and reliability of a helicopter transmission. The computer program uses the lives and reliabilities of the individual components to compute the life and reliability of the transmission.

The life and reliability models are based on the assumption that the transmission is adequately lubricated and well designed. This means that its gears have sufficient rims and are made of adequate materials so that premature tooth breakage will not occur. Also, it is assumed that the tooth form geometry and lubricant have been selected to prevent tip scoring. Both of these failure modes can be prevented [4].

However, surface pitting is not preventable due to the lack of a surface fatigue endurance limit for high strength gears. As with rolling element bearings, gear teeth will fail eventually in surface pitting even in a well designed, well lubricated transmission,

regardless of the loads [5-11]. Thus, the life and reliability models for spiral bevel gear reduction and planetary gear units are based on the pitting fatigue life and reliability models for the bearings and gears in the transmission.

In this program, a modular approach is used in which the force and motion analyses of the reduction are separated from the life and reliability analyses. The dynamic capacity models are also separated algebraically from the prior calculations. In this way, the calculations can be performed sequentially and the complexity and diversity of the analyzed transmissions can be increased greatly.

The computer program can simulate a number of configurations of spiral bevel gear units, dual spiral bevel gear units, planetary gear units and combinations of units. The eight transmission configurations analyzed by this program are shown in figure 1. Configuration 3 is found in the OH-58 light duty helicopter and consists of a spiral bevel gear unit combined with a planetary gear unit. Configuration 8 is found in the Black Hawk helicopter and consists of parallel spiral bevel units combined with a dual spiral bevel gear unit. The power is then transmitted to the rotor through a planetary gear unit. The power inputs to the two input pinions of the dual spiral bevel gear unit do not have to be equal, so that the loss of power in one engine can be simulated. The program also allows the planetary gear unit to be composed of stepped or unstepped planet gears. The program can simulate transmissions at different power levels and load duty cycles. The program can calculate the lives and dynamic capacities of a single unit or the transmission as a whole.

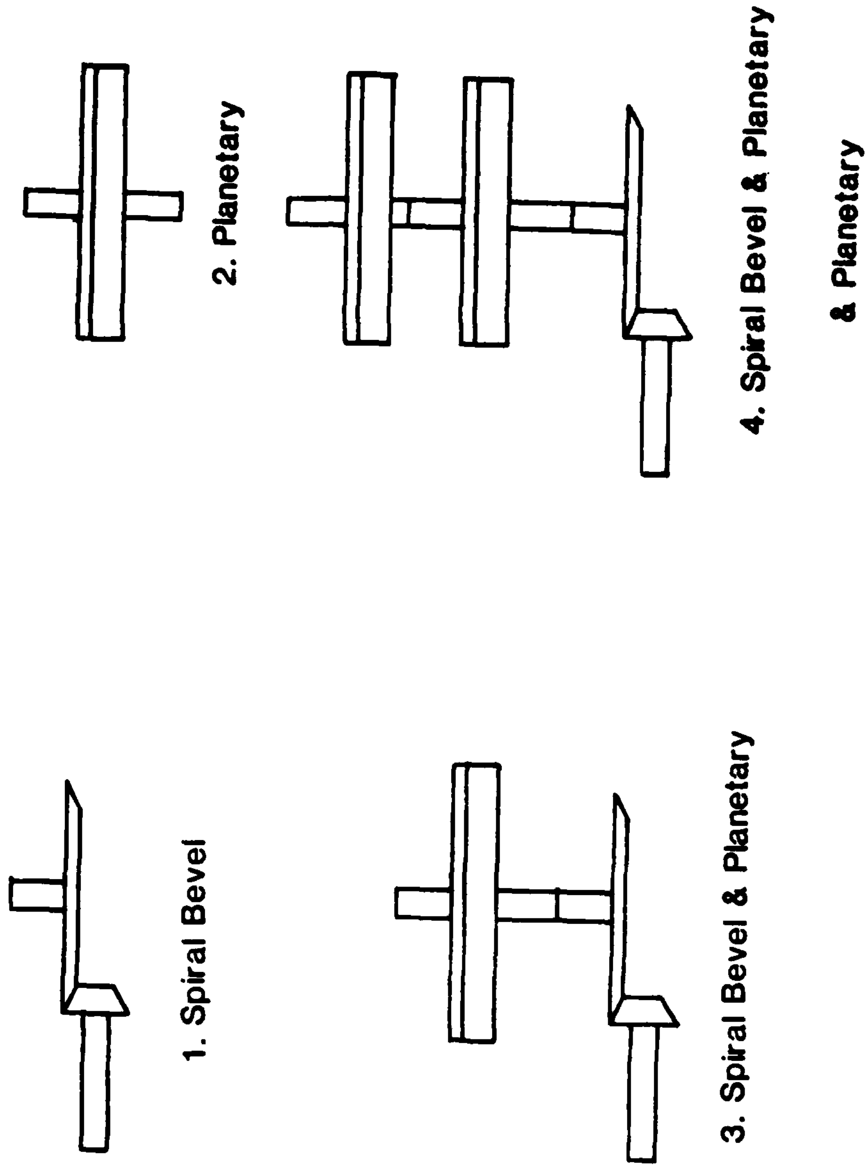


Figure 1

Helicopter Transmission Types

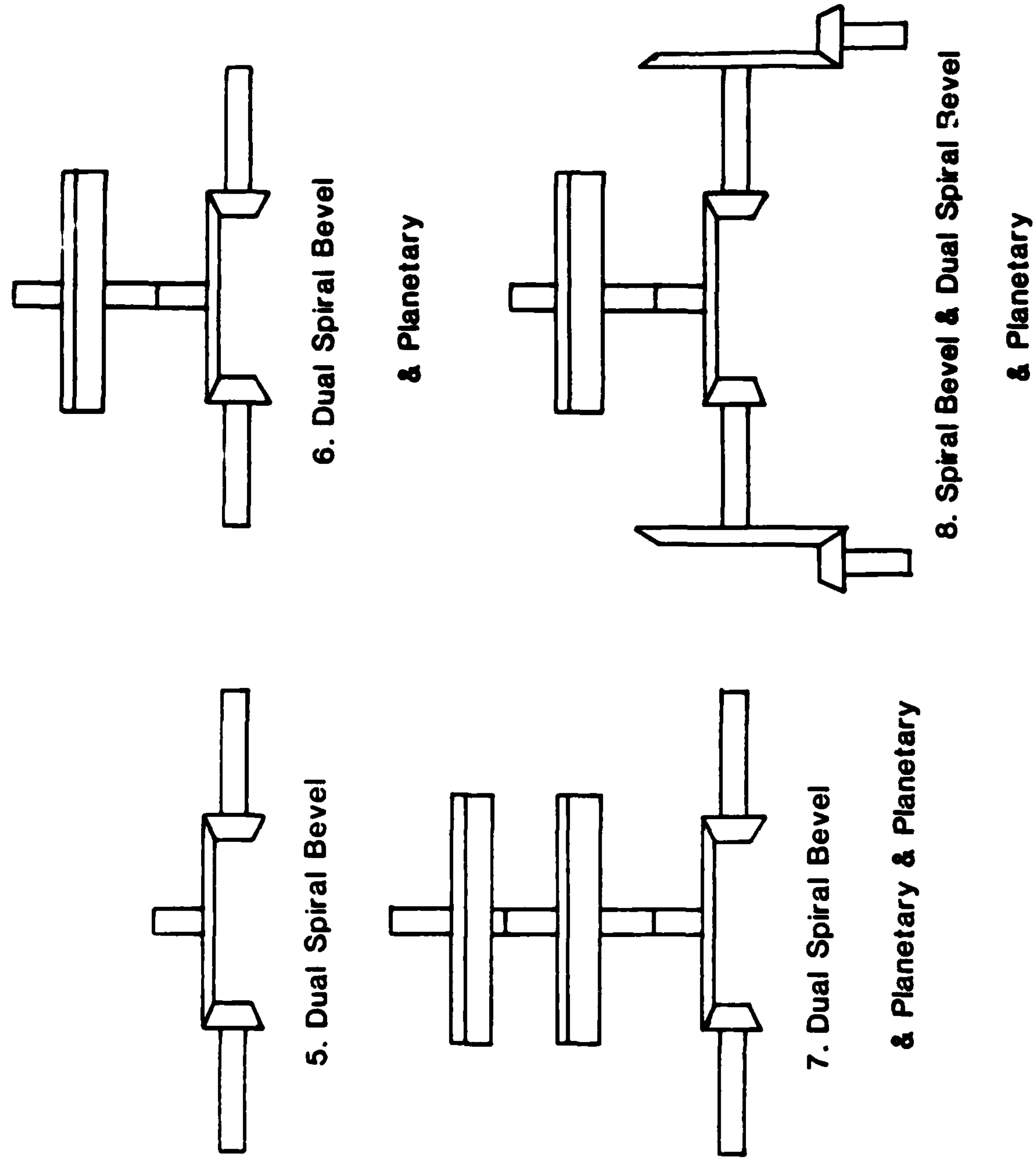


Figure 1 continued

Helicopter Transmission Types

TRANSMISSION POWER FLOW

In a helicopter, power is typically produced by a turbine engine oriented horizontally and close to the main rotor shaft. The rotor shaft is nearly vertical and the power from the turbine must be transmitted through approximately ninety degrees. The transmission must handle a speed reduction from the turbine engine to the rotor shaft in the range of 80:1. To accomplish this in a small amount of space, spiral bevel gear units are used in conjunction with planetary gear units.

In the analysis, the spiral bevel gear units and planetary units are treated separately. Even though the units are treated separately, they must have a common counting base to allow combinations of lives and reliabilities. In helicopters, a significant part is the output rotor shaft. Therefore the common counting base in this program is the output torque and speed of this rotor shaft which is unchanged from design to design.

In helicopters, a common configuration is a spiral bevel gear unit from the turbine followed by a planetary unit along the output shaft. There may be more than one spiral bevel gear unit in series or parallel and there may be more than one planetary gear unit in series

along the output shaft. The couplings between the units are assumed to be splined, only able to transmit torque loads between the units.

Spiral Bevel Gear Unit

For the spiral bevel gear unit there are many inputs which define the geometry [12]. In figure 2, the geometry which is required for analysis of the gear mesh is shown. The main measure of bevel size is the cone distance, A_o. The cone distance is the distance from the apex of the bevel cones to the back edge of the tooth face. This distance is measured along the pitch line of the two pitch cones of the mating gears. The contact face width of the gear set , f, is measured along the same pitch line.

To define the geometry of the pitch cones, the following inputs are required, number of teeth on the pinion, N_p, number of teeth on the gear, N_g, and the shaft angle. The shaft angle is the angle between the input pinion shaft and the output gear shaft. The pitch angles, which are half the cone angle of the gear, are related by these inputs in the following equations.

$$\tan \Gamma_g = \frac{\sin \Sigma}{(N_p/N_g) + \cos \Sigma} \tag{1}$$

$$\tan \Gamma_p = \frac{\sin \Sigma}{(N_g/N_p) + \cos \Sigma} \tag{2}$$

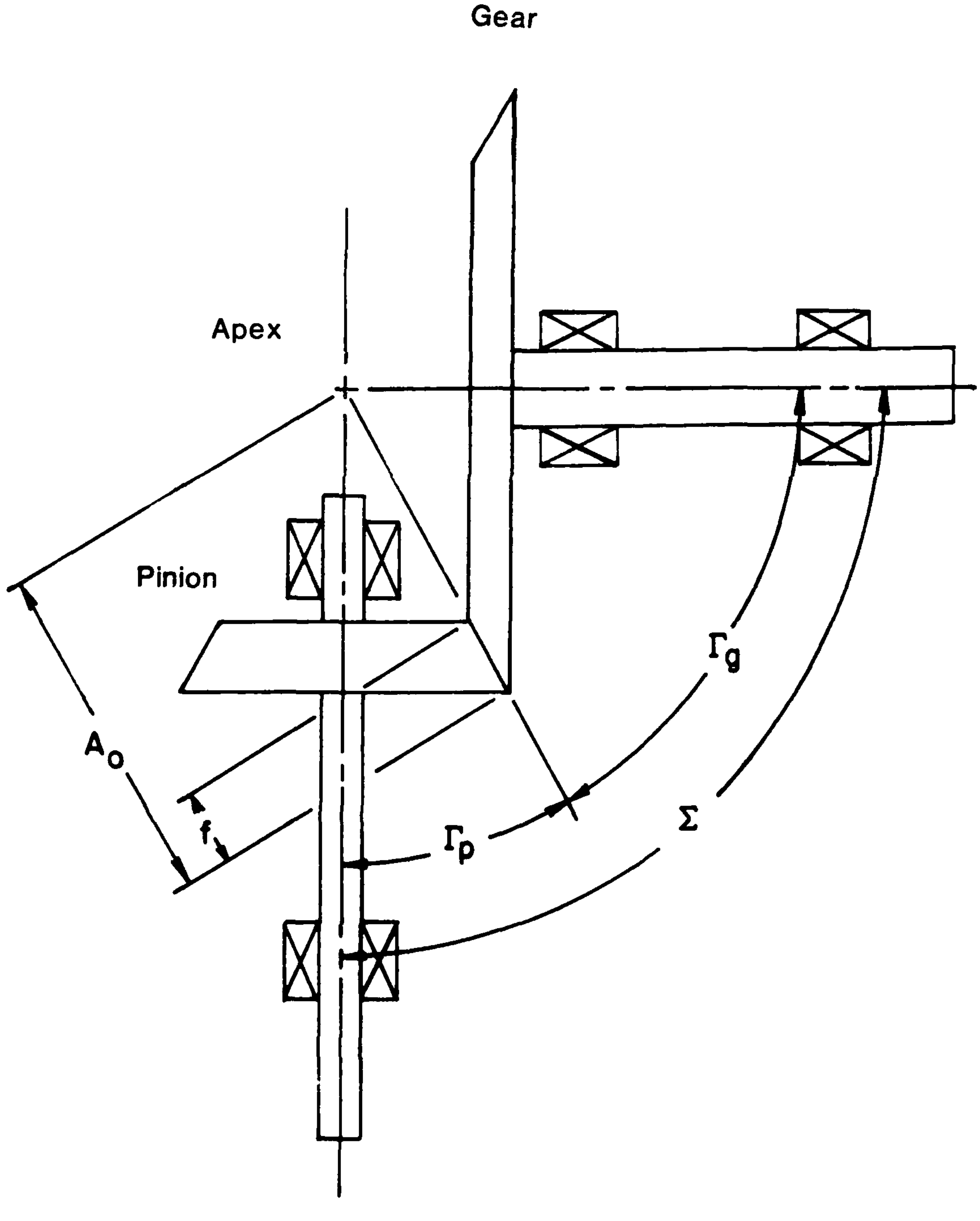


Figure 2

Spiral Bevel Gear Pitch Cone Geometry

The point of gear contact used in the analysis is the pitch point. The distance from the apex to the midpoint of the face locates the pitch point.

$$D_o = A_o - \left(\frac{f}{2}\right) \tag{3}$$

The pitch diameters of the equivalent spur gear for the spiral bevel pinion and gear can be found by:

$$D_p = 2 * D_o * \sin \Gamma_p \tag{4}$$

$$D_g = 2 * D_o * \sin \Gamma_g \tag{5}$$

Also in this analysis, the teeth in the mesh at the pitch point are modeled as planar spur gears. Figure 3 is a composite drawing showing the bevel and reference spur gear. The diameter of the reference planar spur gear is double the backcone distance. The backcone distance is defined as the perpendicular distance from the pitch point at the midpoint of the gear face to the centerline of the gear shaft. The backcone distance of the pinion and gear are calculated by:

$$B_{cp} = \tan \Gamma_p * D_o \tag{6}$$

$$B_{cg} = \tan \Gamma_g * D_o \tag{7}$$

In addition to the size and shape of the pitch surface, the gears are defined by the geometry of the meshing gears. In figure 4 one sees a spiral bevel gear in the pitch plane which is tangent to the pitch cones at the line of contact.

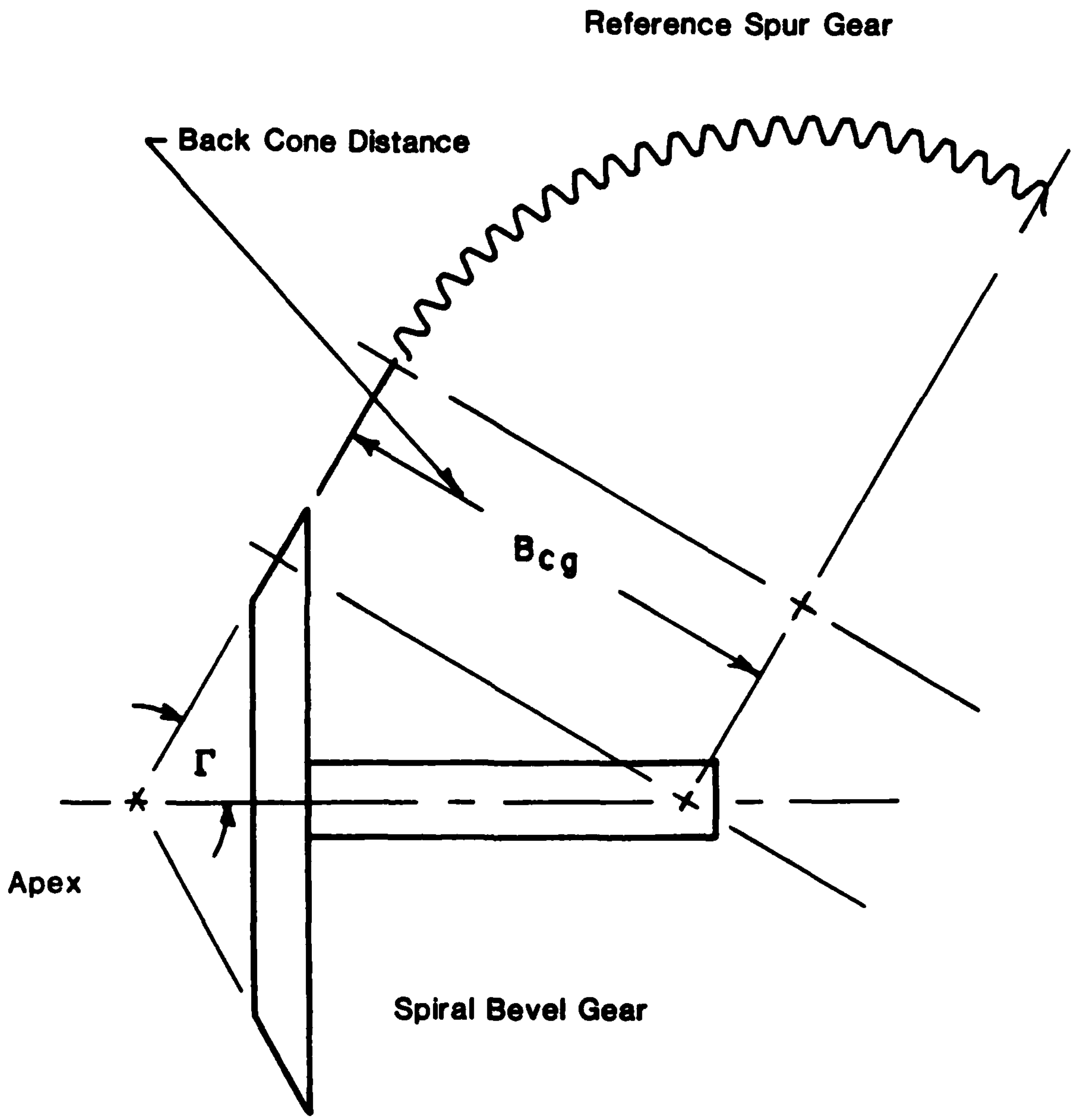


Figure 3

Composite Section of Spiral Bevel Gear and

Reference Planar Spur Gear

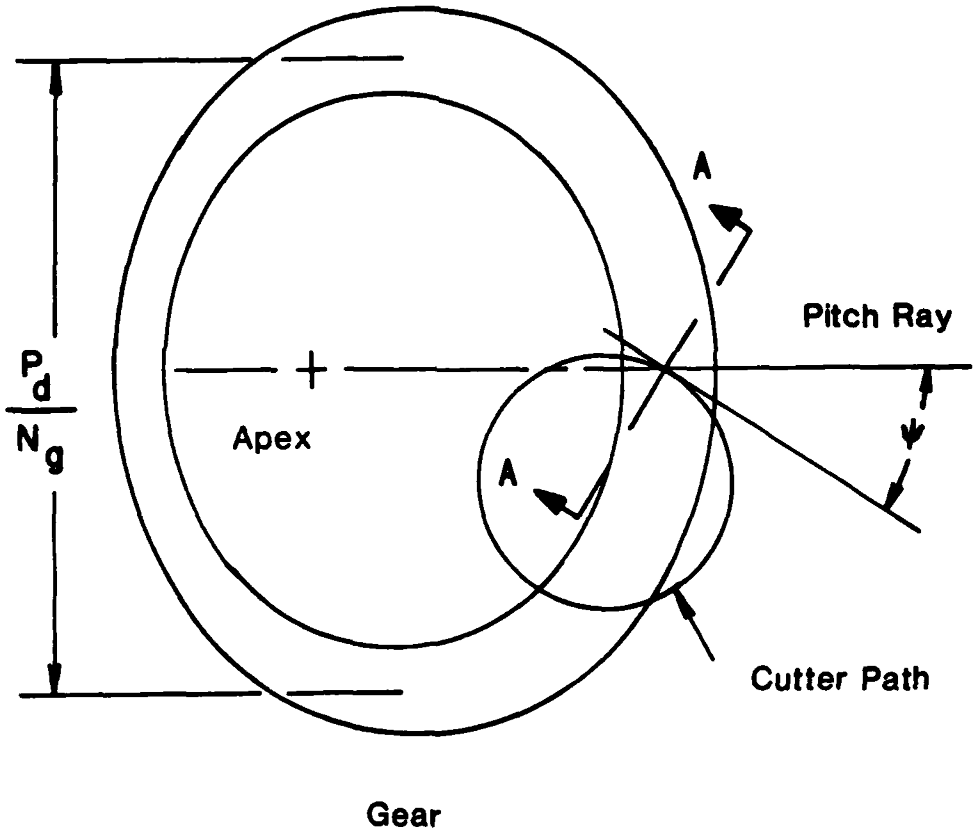


Figure 4

Spiral Angle

In the figure, the spiral angle, Ψ, is shown as the angle between the pitch ray and a tangent to the circular cutter at the mid-point of the tooth. This angle is positive for right hand advance of the spiral along the axis of the gear toward the cone apex. The figure shows a right hand spiral. In the spiral bevel mesh the pinion and the gear must have the same spiral angle but the hands of the meshing gears must be opposite.

The diametral pitch of the teeth is defined at the mid-tooth radius.

$$P_d = \frac{N_g}{2 * D_o * \sin \Gamma_g} \tag{8}$$

It can be noted that the pitches are direct functions of the numbers of teeth on the gears and the pitch cone geometry. Figure 5 shows the normal tooth geometry at the mid-plane of the tooth. Figure 5 corresponds to section AA in figure 4. The normal pressure angle ϕ_n, addendum a_b, and dedendum d_b, are shown at the mid-plane of a bevel tooth.

The direction of rotation of the pinion is required to define the loads transmitted at the point of gear contact. In this paper, clockwise rotation is defined looking at the back of the pinion along the pinion shaft toward the cone apex.

One must also specify the bearing supports of the gears. The two bearing configurations most commonly used, straddle and overhung, are shown in figure 6. In both cases distance A is the distance from

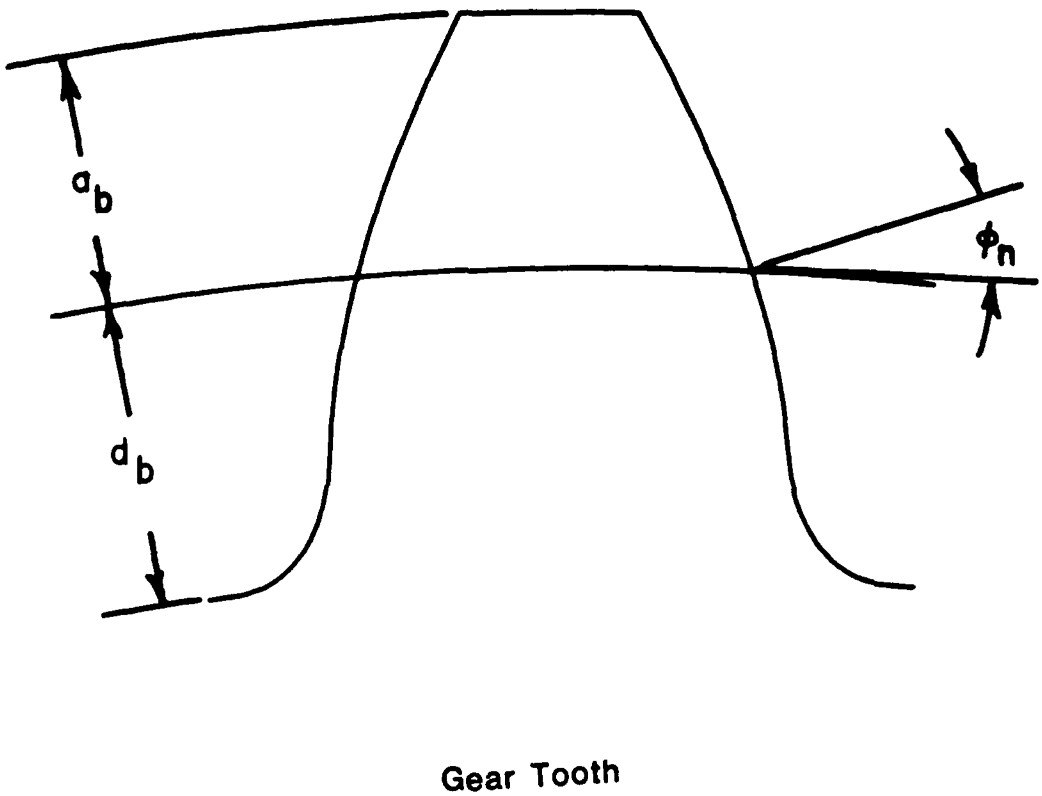
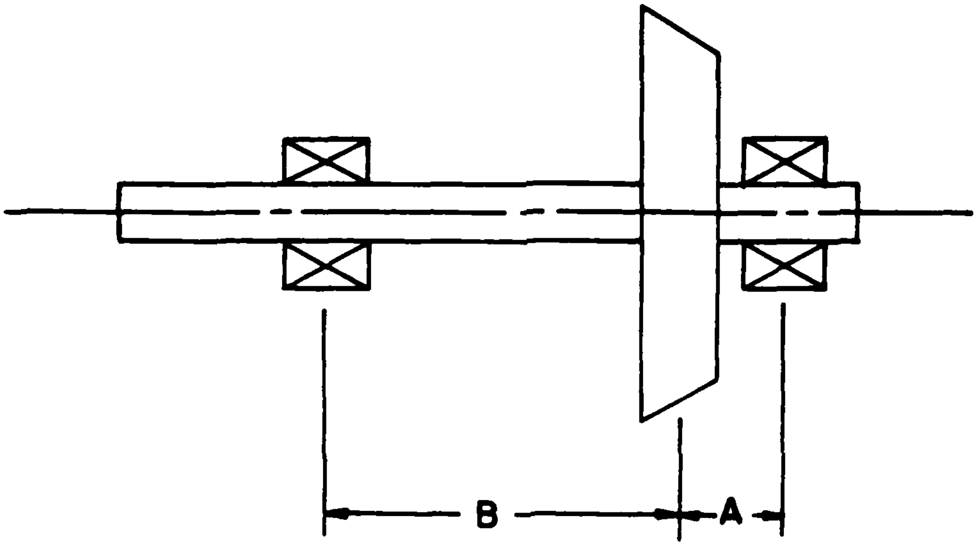
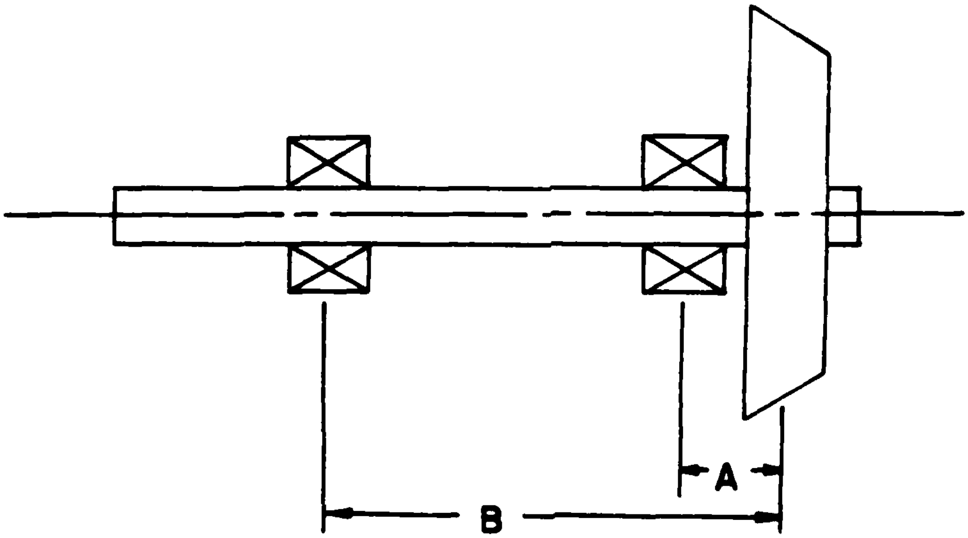


Figure 5

Normal Tooth Geometry



a) Straddle



b) Overhung

Figure 6

Bearing Mounting Configuration

the gear to the bearing closest to the apex. In case 2, distance A takes on a negative value. Distance B is defined as the distance from the gear to the bearing furthest away from the apex. All distances are measured from the mid-point of the gear to the mid-point of the bearing. One bearing on each shaft must be identified as a thrust bearing to take the axial thrust loads produced by the bevel gear mesh.

In the case of dual inputs, the pinions and their mounting are considered to be identical. The only difference can be the load levels applied by the pinions. Figure 7 shows the twin input bevel in the plane of the two input shafts.

Planetary Gear Unit

For the planetary gear unit one must define whether the unit is stepped or non-stepped and the number of planets carried by the planet arm. Figures 8 and 9 show an unstepped and stepped planetary gear unit, respectively, with three planet gears. For the planetary units, the sun gear is the input shaft, the ring gear is fixed and the planet arm is the output shaft. In the case of the non-stepped planetary unit, the number of teeth of the sun gear, planet gear, and ring gear are required. Figure 10 shows a mesh of an unstepped planetary gear unit. In the case of a stepped planetary unit, the number of teeth on the sun gear, planet-sun gear, planet-ring gear, and the ring gear are required. The planet-sun gear is defined as the planet gear meshing with the sun gear in a stepped planetary gear unit. The planet-ring gear is the planet gear meshing with the ring gear in a stepped planetary gear unit. Figure 11 shows a mesh of a stepped planetary

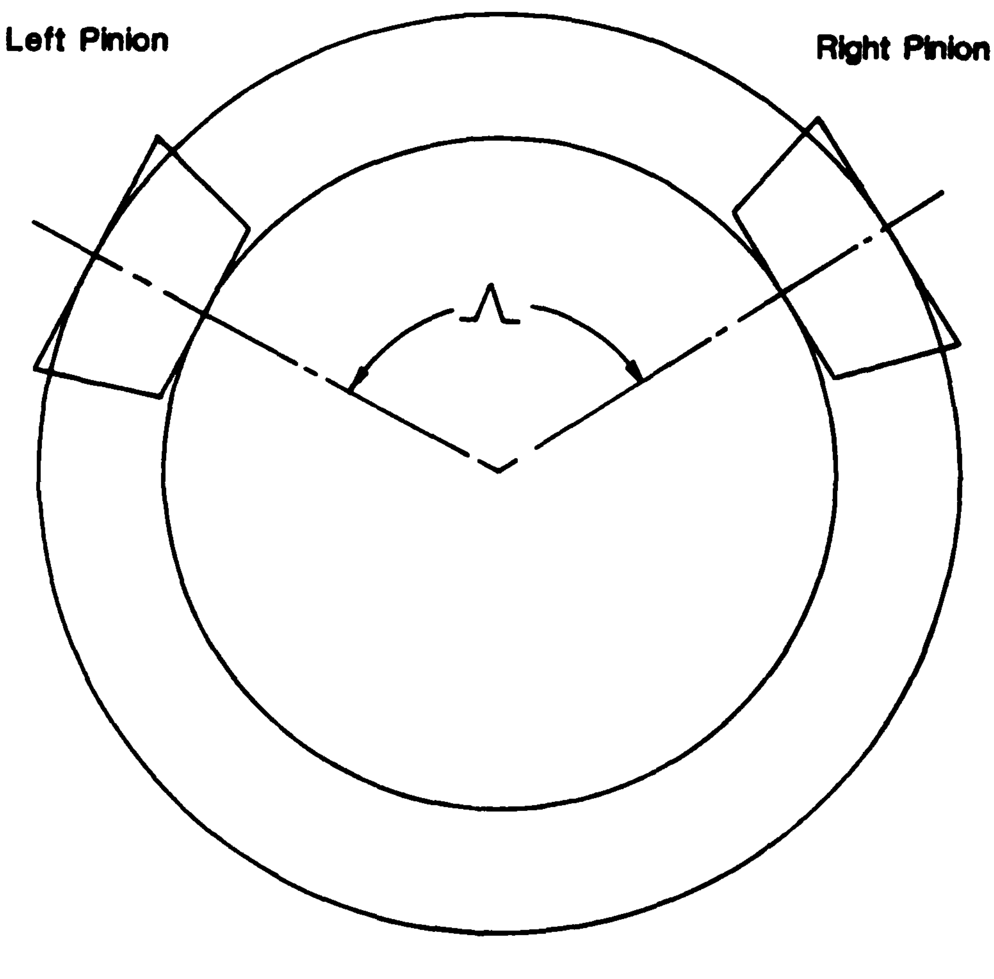


Figure 7

Twin Input Spiral Bevel Gear

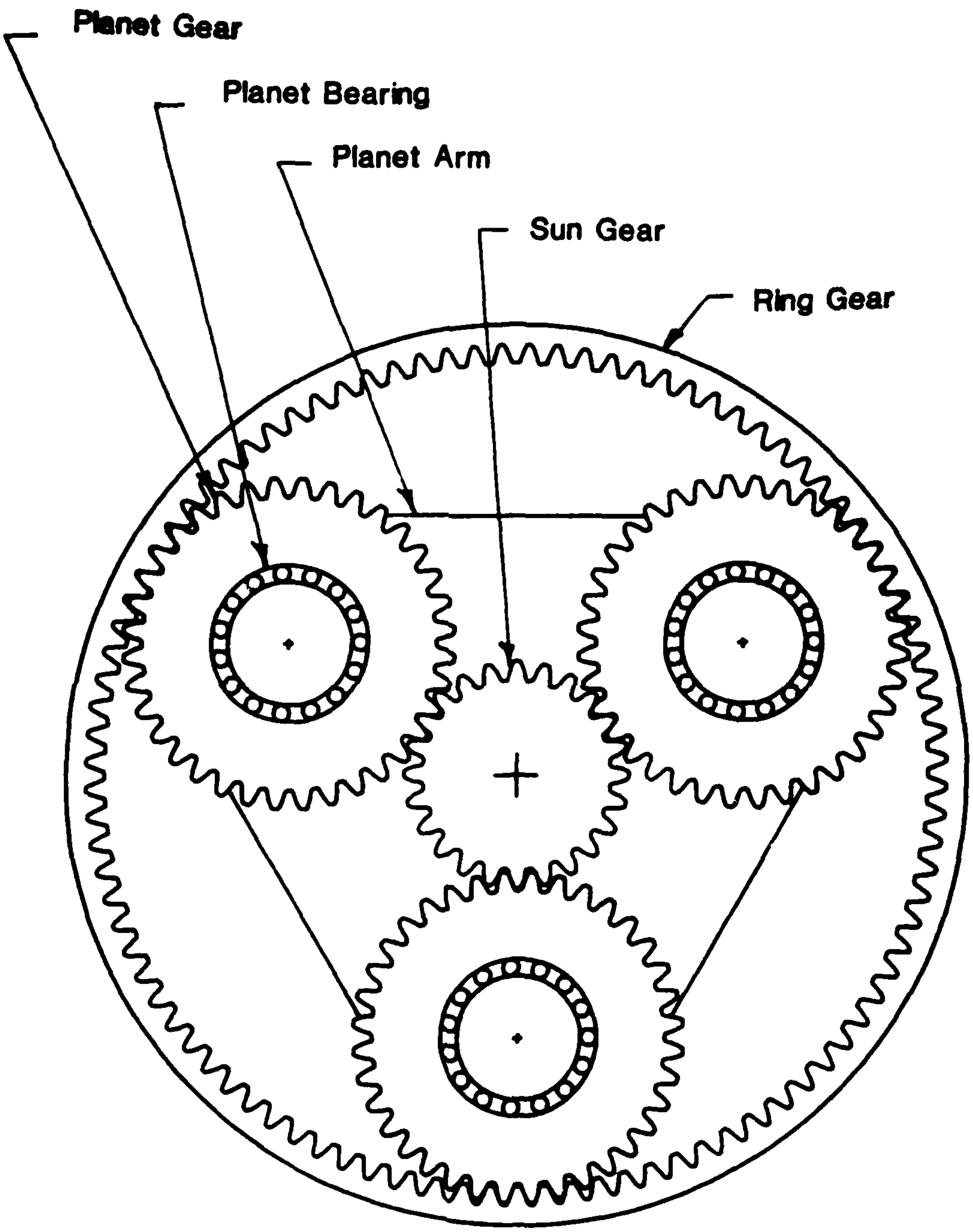


Figure 8

Unstepped Planetary Gear Unit

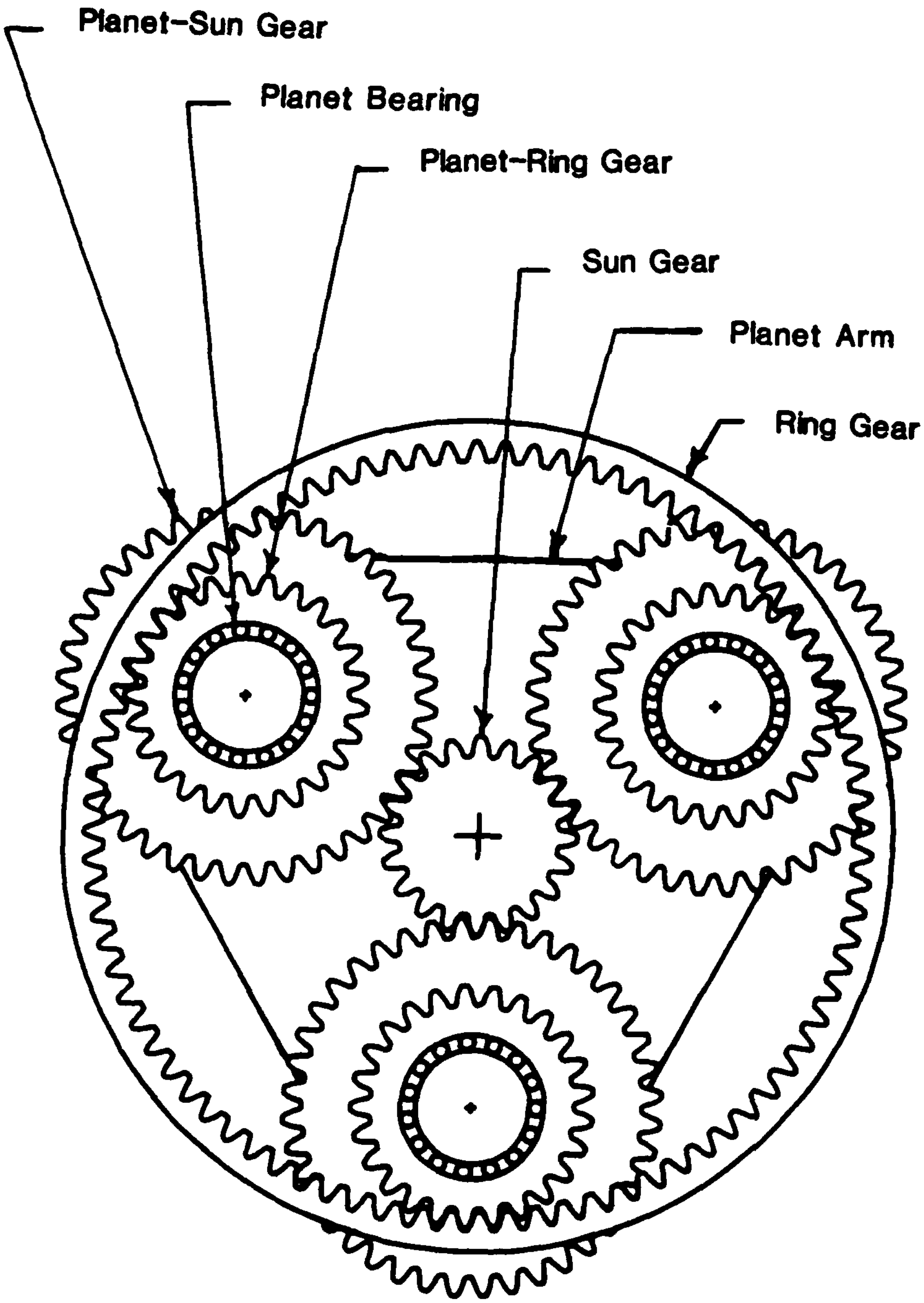


Figure 9

Stepped Planetary Gear Unit

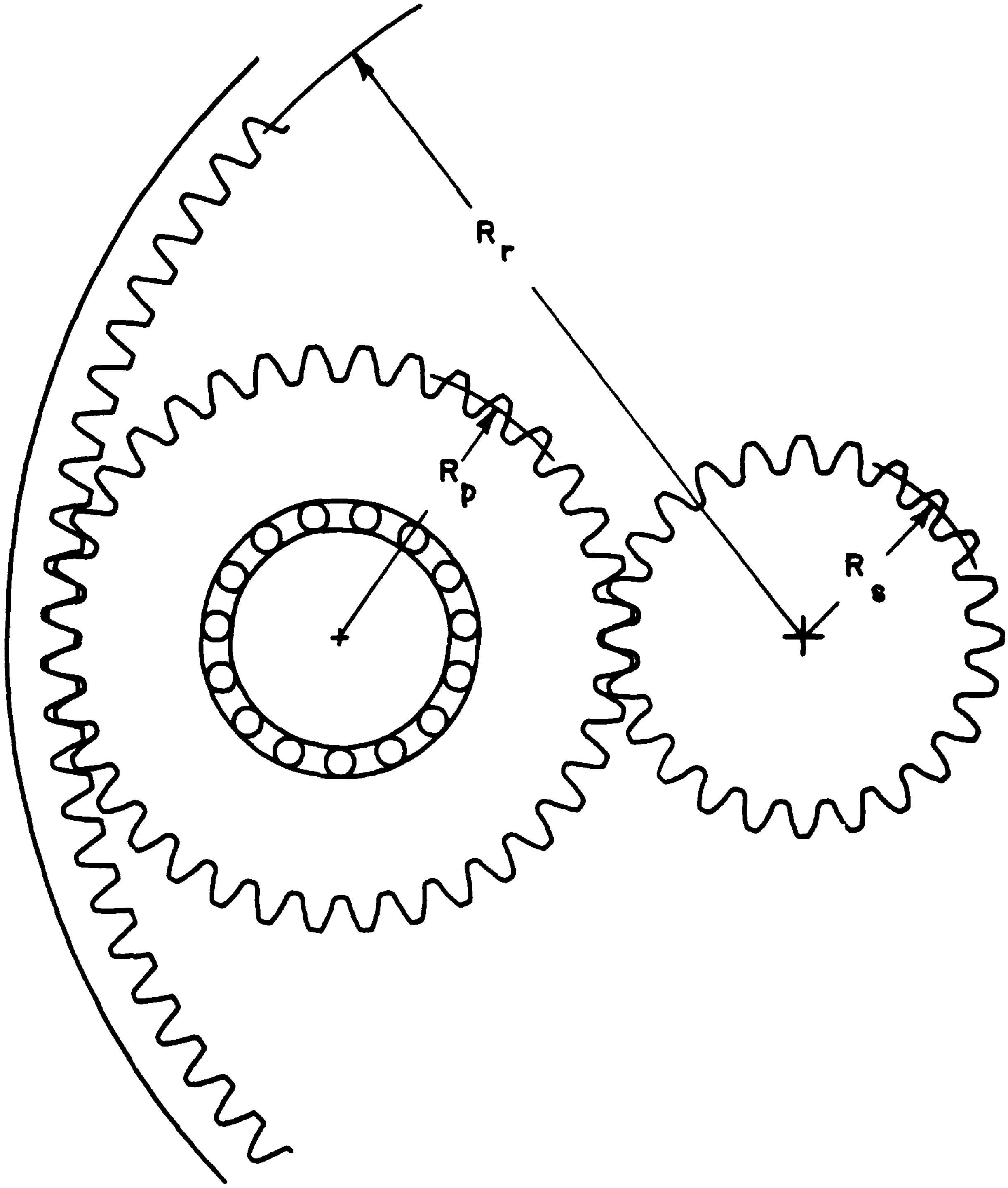


Figure 10

Unstepped Planetary Gear Unit Gear Mesh

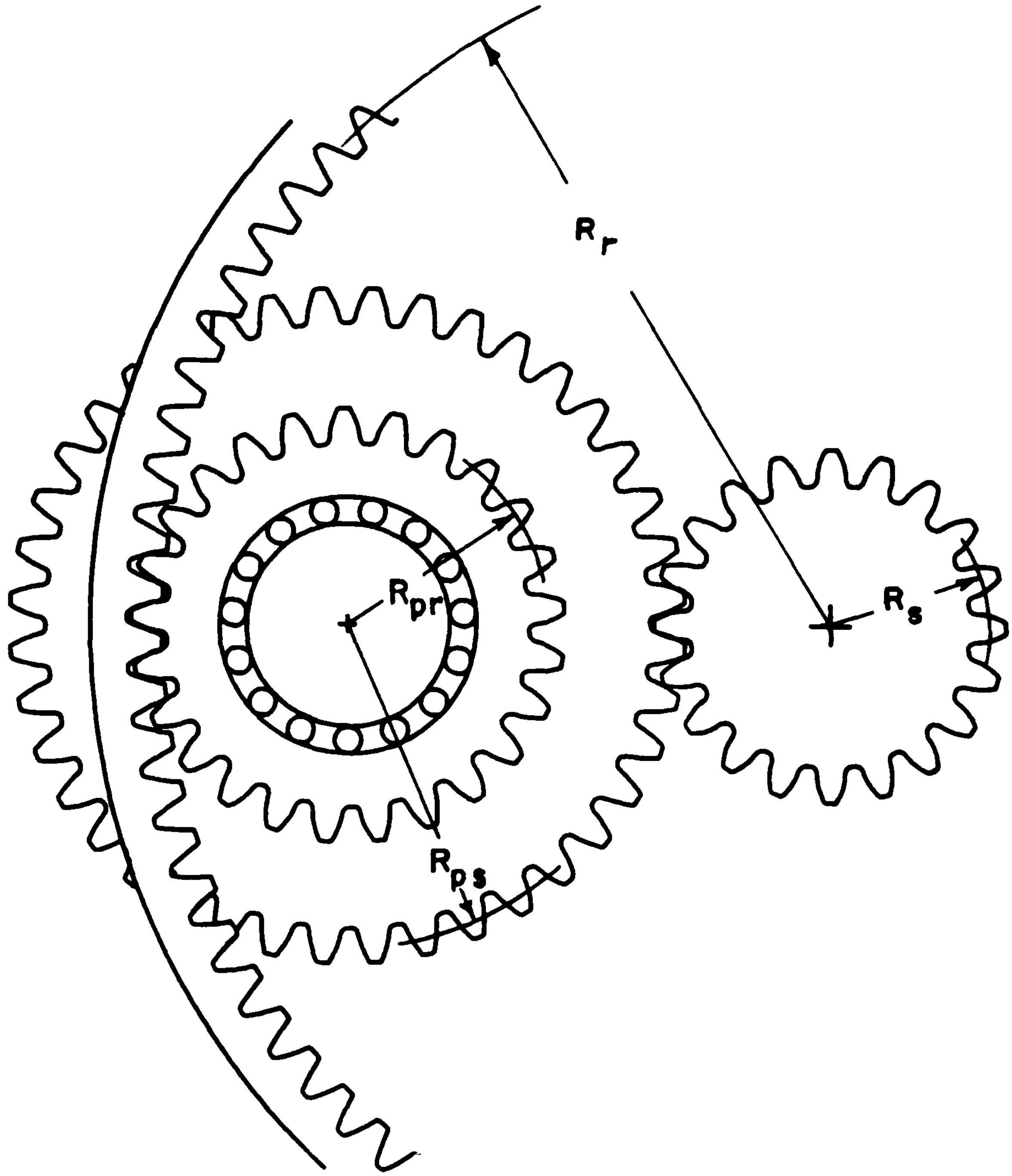


Figure 11

Stepped Planetary Gear Unit Gear Mesh

gear unit. The diametral pitch of the gears in each mesh must be known to define the size of the planetary transmission. The diameter of the gears is found from the diametral pitch, P_d and number of teeth, N.

$$D = N / P_d \tag{9}$$

Due to the motion of the planetary arm carrying the planet gears, each component will not see the same number of load cycles as it would in a fixed axis reduction. Table 1 gives the relationship between one output revolution and the load cycle of each component [13]. The ratios in this table are found by a standard planetary gear motion analysis.

In all units, the mesh material strength must be known to calculate the dynamic capacity of the gear tooth. In the case of the bearings, catalog values of the dynamic capacities must be given. The Weibull exponents must be specified for each component. The load-life exponent must be specified for each gear. The program automatically assumes an exponent of 3.0 for ball bearings and an exponent of 3.333 for roller bearings [14].

TABLE 1

Ratio of the Number of Component Load Cycles

to One Output Shaft Revolution

Planetary Gear Unit

Component	Non-Stepped	Stepped
Sun	$\frac{n*R_r}{R_s}$	$\frac{n*(R_r*R_{ps})}{(R_s*R_{pr})}$
Planet (Sun)	$\frac{R_r}{R_p}$	$\frac{R_r}{R_{pr}}$
Planet (Ring)	$\frac{R_r}{R_p}$	$\frac{R_r}{R_{pr}}$
Ring	n	n
Spider	1.0	1.0

COMPONENT LOADING

The load on each component can be calculated from the applied input torque and the geometry of the components. Due to the many configurations of bearing and gear location, no single formula can be used to calculate the component load. Instead, a series of steps is required to obtain the component load.

Spiral Bevel Gear Unit Loading

The loading on the spiral bevel gear units can be analyzed by calculating the force developed in the gear teeth. This force can be divided into three orthogonal components shown in figure 12.

These forces are the tangential load, Wt, which is produced by the torque on the gear shaft [12,14]. The radial load, Wr, and the axial load, Wa, are produced by the geometry of the gear teeth transmitting the tangential load. These loads are

$$W_t = \frac{T_0}{D_0 * \sin \Gamma_g} \tag{10}$$

$$W_r = \frac{W_t * (\tan \phi_n * \cos \Gamma_g + \sin \psi * \sin \Gamma_g)}{\cos \psi} \tag{11}$$

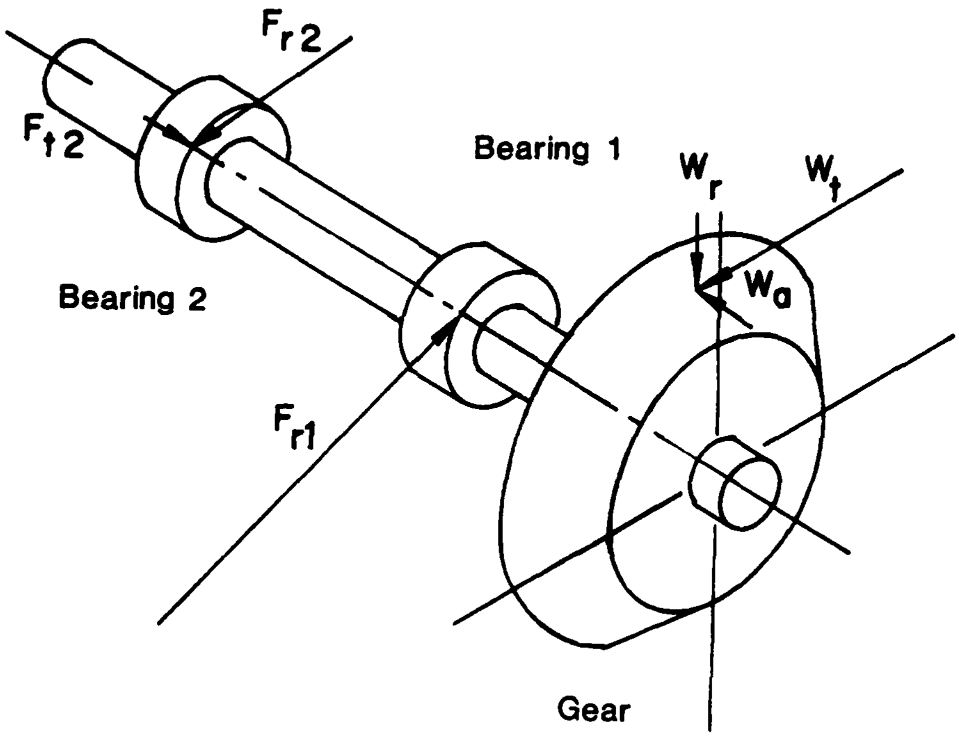


Figure 12

Spiral Bevel Gear Forces

$$W_a = \frac{W_t * (\tan \phi_n * \sin \Gamma_g - \sin \psi * \cos \Gamma_g)}{\cos \psi} \quad (12)$$

In equation 11 and 12, the sign of the last term changes with respect to the spiral hand, direction of gear rotation and whether the gear is driving or being driven. These equations are valid for a driving gear with a right hand spiral which is rotating clockwise. The equations are also good for a driving gear with a left hand spiral which is rotating counterclockwise. For a driven gear, the equations are valid for a right hand spiral gear driven counterclockwise and a left hand spiral gear driven clockwise. For the four other conditions with power flow in the opposite direction, the signs of the equations are switched.

$$W_r = \frac{W_t * (\tan \phi_n * \cos \Gamma_g - \sin \psi * \sin \Gamma_g)}{\cos \psi} \quad (13)$$

$$W_a = \frac{W_t * (\tan \phi_n * \sin \Gamma_g + \sin \psi * \cos \Gamma_g)}{\cos \psi} \quad (14)$$

For a shaft angle of 90 degrees, the radial load of the pinion will be equal to the axial load of the gear. Also the axial load of the pinion will be equal to the radial load of the gear. Regardless of shaft angle, the tangential force will be equal on pinion and gear. Also, the total resultant tooth load on the pinion and the gear must be equal in all cases. The total resultant tooth load is given by:

$$W_n = \sqrt{W_t^2 + W_r^2 + W_a^2} \tag{15}$$

The three force components of the gear will transmit forces to the support bearings. In this analysis one bearing will take the thrust load, transmitted axially from the gear.

$$F_t = W_a \tag{16}$$

The radial forces on the bearings are a result of the moment produced by the axial load on the gear, and the radial and tangential loads. Bearing 1 is the bearing closest to the gear cone apex. Bearing 2 is the bearing furthest away from the cone apex.

Bearing 1

Tangential load

$$F_{t1} = \frac{W_t * B}{A + B} \tag{17}$$

Radial Load

$$F_{r1} = \frac{(W_a * N_g /(2 * P_d)) - W_r * B}{A + B} \tag{18}$$

Combined Radial Load

$$F_{rT1} = \sqrt{F_{t1}^2 + F_{r1}^2} \tag{19}$$

Bearing 2

Tangential load

$$F_{t2} = \frac{W_t * A}{A + B} \tag{20}$$

Radial Load

$$F_{r2} = \frac{(W_a * N_g /(2 * P_d)) + W_r * A}{A + B} \tag{21}$$

Combined Radial Load

$$F_{rT2} = \sqrt{F_{t2}^{2} + F_{r2}^{2}} \tag{22}$$

These equations are good for any pinion and a gear loaded by one pinion. In the case of straddle mounted gear, distance A is considered to be positive. In the overhung case, distance A is considered negative. For the case of dual pinion input, each bearing carries two sets of tangential and radial loads which can be reduced into one tangential and radial load. The direction of the combined tangential and radial loads is taken to be the direction of the load from the contact with the right pinion. The resultant of these two orthogonal components is the total radial load on the bearing. The vectoral combination of the forces into one total radial load is shown in figure 13. The axial load on the bearing is the sum of the reactions of the right and left pinion axial gear forces. The total torque output from the gear is also the sum of the two pinion gear torques on the output gear.

Combined Radial Load

$$F_R = F_{rr} + F_{rl} * \cos \Lambda - F_{tl} * \sin \Lambda \tag{23}$$

Combined Tangential Load

$$F_T = F_{tr} + F_{rl} * \sin \Lambda + F_{tl} * \cos \Lambda \tag{24}$$

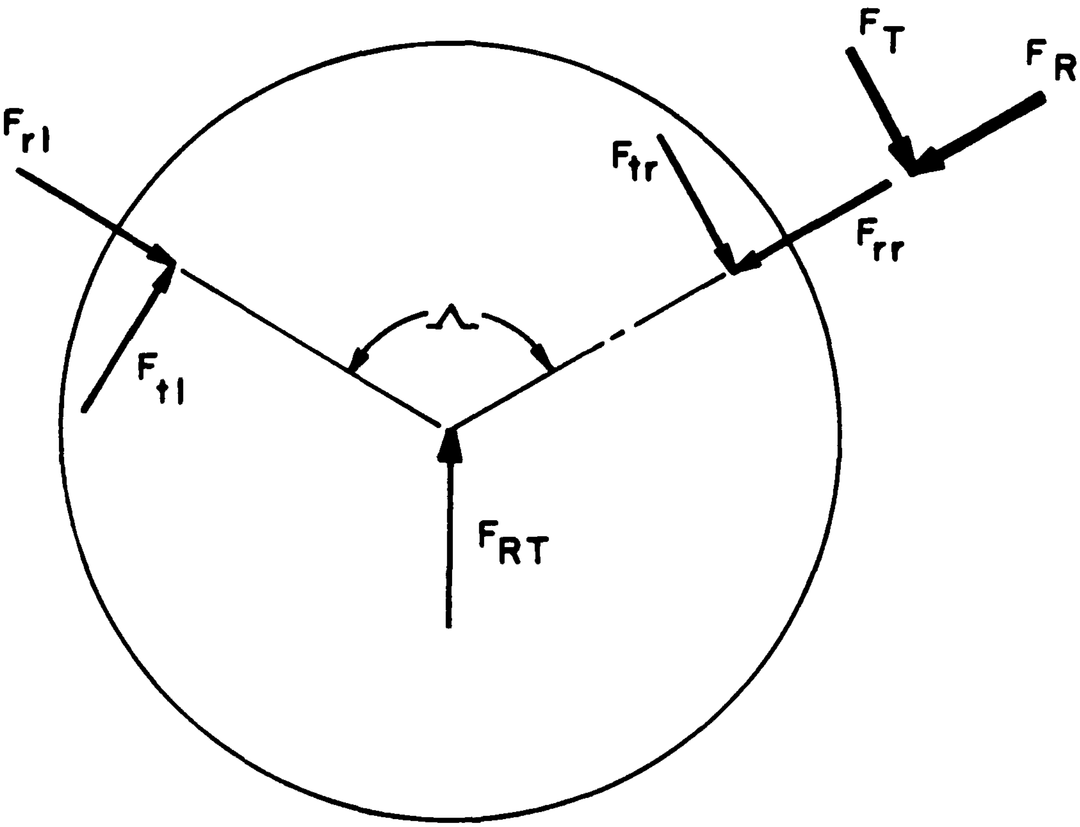


Figure 13

Dual Spiral Bevel Gear Forces

Total Radial Load

$$F_{RT} = \sqrt{F_R^2 + F_T^2} \tag{25}$$

Planetary Gear Unit Loading

In the planetary gear unit all loads on the components are either tangential or radial. All loads are assumed to be acting in the same plane. It is assumed that each planet gear carries an equal amount of the input torque of the sun gear.

For the sun or planet gear, the tangential force on a tooth at each sun-planet gear mesh is :

$$F_S = \frac{T_i}{n * R_S} \tag{26}$$

The tangential force on a tooth of the ring or planet gear in each ring - planet mesh is :

$$F_R = \left(\frac{R_{ps}}{R_{pr}}\right) * \left(\frac{T_i}{n * R_s}\right) \tag{27}$$

Figure 14 shows the loading on the planet gear from the sun - planet and ring - planet gear meshes. The total tangential force on the planet gear bearing is :

$$F_t = F_R + F_S \tag{28}$$

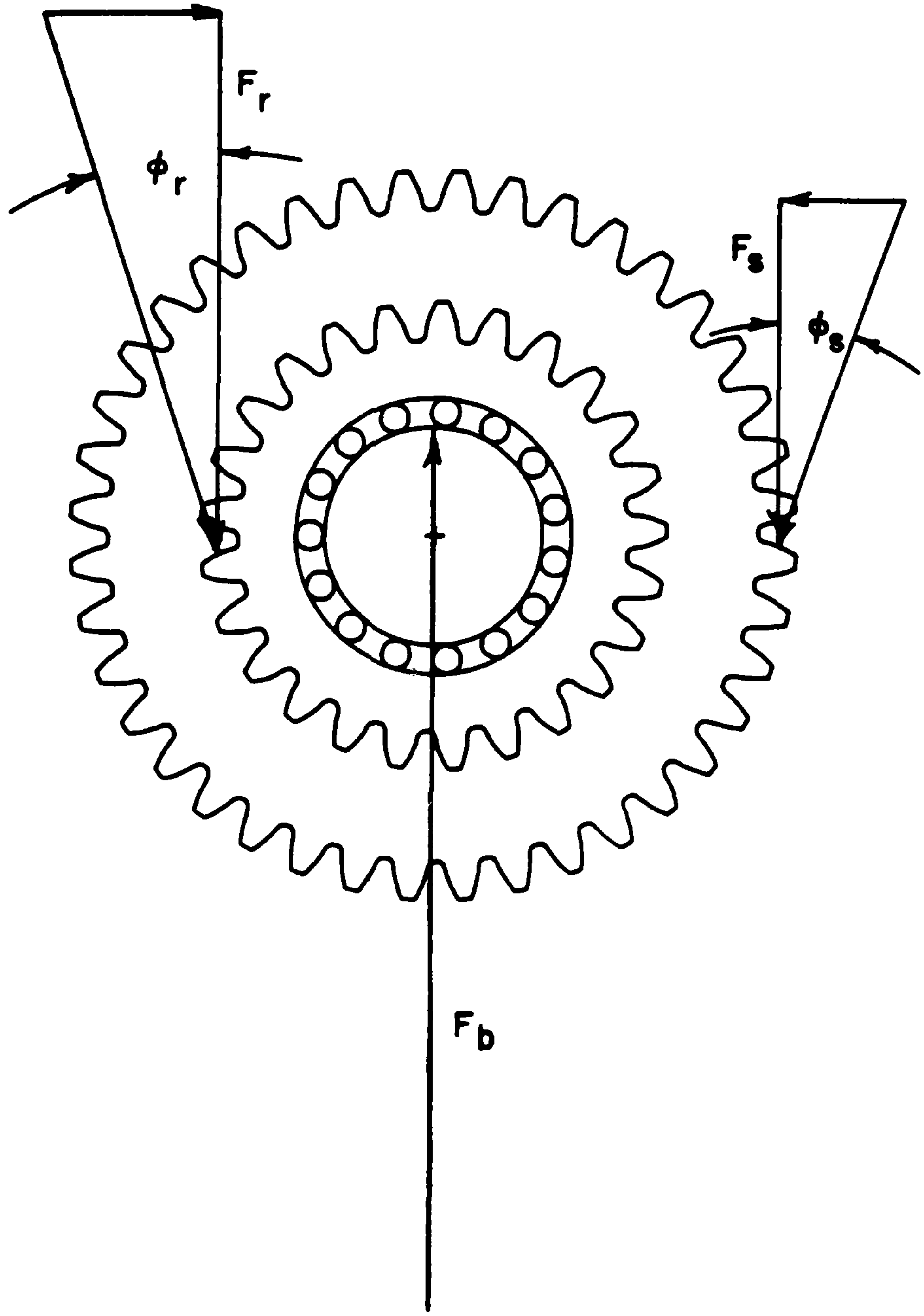


Figure 14

Planet Gear Forces

The bearing may also see a radial load due to the radial components produced by the pressure angle of the gear meshes.

$$F_r = F_R * \tan \phi_r - F_S * \tan \phi_s \tag{29}$$

The total load on the bearing is :

$$F_T = \sqrt{F_t^2 + F_r^2} \tag{30}$$

LIFE AND DYNAMIC CAPACITY

Life and Dynamic Capacity Models

Surface pitting fatigue from cyclic loading is the mode of failure for the components considered in this simulation program for the life of a helicopter transmission. Loaded surfaces of rolling element bearings and the gears, will fail due to surface pitting after a number of repeated loadings. The model used to predict failure which relates the number of load cycles at failure to the applied load is Palmgren's model. Palmgren's model was originally developed for rolling element bearings. It has also been applied to gear teeth in this computer simulation program. The Palmgren model is:

$$l_{10} = \left(\frac{C}{F}\right)^{p} \tag{31}$$

l_{10} is the life of the component in millions of load cycles for a 90 percent probability of survival [15,16]. F is the equivilent load on the component. C, the basic dynamic capacity, is the reference load for which 90 percent of a large sample of the components will survive one million load cycles. The exponent p is called the load-life factor.

Equation 31 is the analytical expression for a load verses life diagram in which there is no endurance limit. Using the Palmgren-Minor linear damage rule and equation 31 an equivalent nominal load for a component in terms of a mission spectrum of loads can be obtained as:

$$F = \left(\frac{F_a^{\,p} * L_a + F_b^{\,p} * L_b + \ldots}{L_a + L_b + \ldots} \right)^{(1/p)} \tag{32}$$

Where L_a is the life at load F_a.

The model for component life as a function of load has been combined with the Weibull distribution for probability of survival as a function of life at a given load for ball and roller bearings [15,16] and for gear teeth [5-9]. The equation resulting from the combination describes the life and reliability as a function of the applied equivalent load. The two parameter Weibull distribution is:

$$\log\left(\frac{1}{S}\right) = \log\left(\frac{1}{0.9}\right) * \left(\frac{l}{l_{10}}\right)^{e} \tag{33}$$

Here, S is the reliability which is also the probablity of survival. l is the component life at the reliabilty S. l_{10} is the component life at 90 percent reliability, and e is the Weibull slope.

The transmission life and reliability models used in this program combine these models for the components with a strict series probability law that states that the probability of survival of the transmission is the product of the probabilities of survival of the components:

$$S_T = S_1 * S_2 * S_3 * \ldots \qquad (34)$$

This strict series probablity law is justified on the basis of the high speed of the transmission components and the effect of loose debris. If any component fails, debris present in the transmission can accelerate wear damage of other components of the transmission. In the case of a transmission run until failure occurs in one component, a complete transmission overhaul is required. The complete overhaul is recommended to repair all components which could have been damaged by debris of the failed component. The overhaul would return the transmission to a high state of reliability.

Component Dynamic Capacity

Each bearing and gear in a transmission has a load which will cause ten percent of a large sample of these components to fail by pitting at or before one million load cycles. This is the component dynamic capacity.

The dynamic capacity for bearings, C_b, can be obtained from the manufacturer of the bearing. The load-life exponent for rolling element

bearings are normally taken as p_b=3.0 for ball bearings and as p_b=3.33 for cylindrical and tapered roller bearings [19].

For gears, the dynamic capacity is not tabulated directly. The dynamic capacity of a gear tooth is proportional to the Hertzian contact pressure squared for applications in which the major axis of the contact ellipse is significantly larger than the minor axis. In spur gears there is line contact. With this proportionality, the dynamic capacity of a gear tooth, C_t, can be expressed as:

$$C_t = \frac{B_1 * b}{\sum\rho} \tag{35}$$

Where B1 is the material constant, b is the length of the major axis of the contact ellipse or line contact and $\sum\rho$ is the curvature sum in the direction of gear tooth rotation. The material constant, B_1, is the experimental load-stress factor, K_1 of Buckingham [17].

Component System Lives - Gears

To obtain the system life of a gear in a transmission the component life of a single tooth of the gear has to be calculated. The load cycles it sees must be adjusted to the output shaft rotations [18,19,20]. Gears with more than one loading are treated separately.

Using a strict series reliability model we can convert the reliability of a single gear tooth to the reliability of a gear.

$$S_g = S_t^{N_g} \tag{36}$$

Where, S_g, is the probability of survival of the gear, S_t is the probability of survival of the gear tooth, N_g is the number of teeth on the gear. If the reciprocal of this equation is taken, the result is:

$$\left(\frac{1}{S_g}\right) = \left(\frac{1}{S_t}\right)^{N_g} \tag{37}$$

Taking the natural logarithm of the equation :

$$\log\left(\frac{1}{S_g}\right) = N_g * \log\left(\frac{1}{S_t}\right) \tag{38}$$

Substituting equation 33, which relates reliability to l_{10} life, into equation 38 yields :

$$\log\left(\frac{1}{0.9}\right) * \left(\frac{L_g}{L_{g10}}\right)^{e_g} = N_g * \log\left(\frac{1}{0.9}\right) * \left(\frac{L_t}{L_{t10}}\right)^{e_g} \tag{39}$$

Where, L_g is the life of the gear, L_{g10} is the 90 percent reliability of the gear, L_t is the life of the gear tooth, L_{t10} is the 90 percent reliability life of the gear tooth, and e_g is the Weibull exponent of the gear. Cancelling terms and taking the equation to the $(1/e_g)$ power yields :

$$\left(\frac{l_g}{l_{g10}}\right) = N_g^{(1/e_g)} * \left(\frac{l_t}{l_{t10}}\right) \tag{40}$$

The equation relating gear tooth dynamic capacity and load to gear tooth life is:

$$l_{t10} = \left(\frac{C_t}{W_n}\right)^{p_g} \tag{41}$$

Where, C_t is the dynamic capacity of a gear tooth and W_n is the load on the gear tooth. This equation can be substituted into equation 40 to yield.

$$\left(\frac{l_g}{l_{g10}}\right) = N_g^{(1/e_g)} \left[\frac{l_t}{\left(\frac{C_t}{W_n}\right)^{p_g}}\right] \tag{42}$$

This equation relates gear life to tooth load. W_n, is the normal tooth load on a single pinion input. When there is a dual pinion input to a gear an equivalent gear tooth load is used. Since the loads from the two pinions may differ, an equivalent load must be used to simulate the same fatigue damage as the two separate loads. To derive the equivalent load we use equation 32.

$$F = \left(\frac{F_a^{\,p} * L_a + F_b^{\,p} * L_b}{L_a + L_b}\right)^{(1/p)} \tag{43}$$

Substituting W_{n1}, the right pinion normal load, and W_{n2}, the left pinion normal load, and substituting, L, for the number of cycles for each pinion.

$$W_{ne} = \left(\frac{W_{n1}^{\,p} * L + W_{n2}^{\,p} * L}{L + L} \right)^{(1/p)} \qquad (44)$$

Cancel terms:

$$W_{ne} = \left(\frac{W_{n1}^{\,p} + W_{n2}^{\,p}}{2.0} \right)^{(1/p)} \qquad (45)$$

This equivalent load is a weighted average of the two loads. W_{ne}, is substituted for W_n in the dual input.

In equation 42 the gear tooth load cycles will not always equal the number of gear rotations. Also the gear rotations will not always equal the output shaft rotations. To get all components on the same counting base, a factor must be inserted. The relationship between output rotations, l_g, and tooth load cycles, l_t, is:

$$l_g = \left(\frac{1}{mg} \right) * l_t \qquad (46)$$

The factor mg is a combination ratio:

$$m_g = m_1 * m_{g2} \qquad (47)$$

Where, m_1 is the gear ratio from the unit output shaft to the final output shaft of the transmission, and m_{g2} is the ratio from tooth load cycles to the unit output shaft. m_{g2} can be found in table 2.

TABLE 2

Ratio Relating Gear Tooth Load Cycles to Unit Output Shaft Rotations

spiral bevel	single input	dual input
pinion	$\frac{N_g}{N_p}$	$\frac{N_g}{N_p}$
gear	1.0	2.0

planetary	non-stepped	stepped
sun	$\frac{n*R_r}{R_s}$	$\frac{n*(R_r*R_s)}{(R_s*R_{pr})}$
planet	$\frac{R_r}{R_p}$	$\frac{R_r}{R_{pr}}$
ring	n	n

If the factor m_g of equation 46, is substituted into equation 42 a relation to calculate gear life in output rotations from the gear tooth load is obtained.

$$l_{g10} = \left(\frac{1}{N_g}\right)^{(1/e_g)} \left(\frac{1}{m_g}\right) \left(\frac{C_t}{W_t}\right)^{p_g} \qquad (48)$$

There is one exception to this equation. In the case of a non-stepped planet gear in a planetary unit, the gear will mesh with two different gears. Since the planet gear meshes with two different gears, the life analysis must take into account the different levels of damage done in each gear mesh [19]. The probability of survival for the planet gear, S_p, is the product of the probability of survival of the teeth in the planet-sun mesh, S_{ps} and the probability of survival of the teeth in the planet-ring mesh, S_{pr}.

$$S_p = S_{ps}^{N_p} * S_{pr}^{N_p} \qquad (49)$$

The probabilities can be combined under one power, since the power of the two probabilities is the same.

$$S_p = (S_{ps} * S_{pr})^{N_p} \qquad (50)$$

Take the reciprocal of the equation

$$\frac{1}{S_p} = \frac{1}{(S_{ps} * S_{pr})^{N_p}} \tag{51}$$

Take the logarithm

$$\log \frac{1}{S_p} = N_p * \log \left[\frac{1}{(S_{ps} * S_{pr})}\right] \tag{52}$$

By expanding equation 52, the relation is seen to be similar to the Weibull distribution, equation 33:

$$\log \left(\frac{1}{S_p}\right) = N_p * \left[\log \left(\frac{1}{S_{ps}}\right) + \log \left(\frac{1}{S_{pr}}\right)\right] \tag{53}$$

Substitute equation 33, relating reliability to L_{10} life into the expanded equation to yield:

$$\log \left(\frac{1}{0.9}\right) * \left(\frac{L_p}{L_{p10}}\right)^{e_g} = N_p * \left[\log \left(\frac{1}{0.9}\right) * \left(\frac{L_{pt}}{L_{ps10}}\right)^{e_g} + \log \left(\frac{1}{0.9}\right) * \left(\frac{L_{pt}}{L_{pr10}}\right)^{e_g}\right] \tag{54}$$

Where L_p and L_{pt} are the lives of the planet gear and planet gear tooth respectively. L_{p10}, L_{ps10}, and L_{pr10} are the 90 percent probability of survival life of the planet gear, of a gear tooth in the planet-sun mesh, and of a gear tooth in the planet-ring mesh respectively. e_g is the gear Weibull exponent. Cancel terms and factor common terms:

$$\left(\frac{L_p}{L_{p10}}\right)^{e_g} = N_p * L_{pt}^{e_g} * \left[\left(\frac{1}{L_{ps10}}\right)^{e_g} + \left(\frac{1}{L_{pr10}}\right)^{e_g}\right] \tag{55}$$

Combine fractions:

$$\left(\frac{L_p}{L_{p10}}\right)^{e_g} = N_p * L_{pt}^{e_g} * \left[\frac{L_{pr10}^{e_g} + L_{ps10}^{e_g}}{L_{ps10}^{e_g} * L_{pr10}^{e_g}}\right] \tag{56}$$

By taking the reciprocal and rearranging the terms the following relation is found:

$$L_{p10}^{e_g} = \left(\frac{1}{N_p}\right) * \left(\frac{L_p}{L_{pt}}\right)^{e_g} * \left[\frac{L_{pr10}^{e_g} * L_{ps10}^{e_g}}{L_{ps10}^{e_g} + L_{pr10}^{e_g}}\right] \tag{57}$$

Take the equation to the e_g th root

$$L_{p10} = \left(\frac{1}{N_p}\right)^{(1/e_g)} * \left(\frac{L_p}{L_{pt}}\right) * \frac{L_{pr10} * L_{ps10}}{\left[L_{ps10}^{e_g} + L_{pr10}^{e_g}\right]^{(1/e_g)}} \tag{58}$$

Sustitute the m_g factor for relating output revolutions to tooth load cycles.

$$L_{p10} = \left(\frac{1}{N_p}\right)^{(1/e_g)} * \left(\frac{1}{m_g}\right) * \frac{L_{pr10} * L_{ps10}}{\left[L_{ps10}^{e_g} + L_{pr10}^{e_g}\right]^{(1/e_g)}} \tag{59}$$

Substitute equation 31 relating tooth life to tooth dynamic capacity and load.

$$L_{p10} = \left(\frac{1}{N_p}\right)^{(1/eg)} * \left(\frac{1}{m_g}\right) * \frac{\left(\frac{C_{pr}}{W_{pr}}\right)^{p_g} * \left(\frac{C_{ps}}{W_{ps}}\right)^{p_g}}{\left[\left(\frac{C_{pr}}{W_{pr}}\right)^{(p_g * e_g)} + \left(\frac{C_{ps}}{W_{ps}}\right)^{(p_g * e_g)}\right]^{(1/e_g)}} \tag{60}$$

Where C_{pr} and C_{ps} are the dynamic capacities of a tooth in the planet-ring gear mesh and a tooth in the planet-sun gear mesh respectively. W_{pr} and W_{ps} are the load on a tooth in the planet-ring and planet-sun mesh respectively. p_g is the load-life exponent of the gear.

Component System Lives - Bearings

Using a similar approach to the gears [18,19,20], the relationship obtained for bearings is:

$$\frac{L_{bs}}{L_{bs10}} = \frac{L_b}{L_{b10}} \tag{61}$$

Where L_b is the life of the bearing in terms of bearing cycles, L_{bs} is the life of the bearing in terms of output shaft revolutions. L_{b10} is the 90 percent reliability life in terms of bearing cycles. L_{bs10} is the 90 percent reliability life in terms of output shaft revolutions. By substituting equation 31, which relates bearing life to bearing capacity and load, the relationship becomes:

$$\left(\frac{L_{bs}}{L_{bs10}}\right) = \left[\frac{L_b}{\left(\frac{C_b}{W_b}\right)^{p_b}}\right] \tag{62}$$

In equation 62 the bearing load cycles will not always equal the number of output shaft rotations. To get all components on the same counting base a factor must be inserted. The relationship relating output rotations, L_{bs}, and bearing load cycles, L_b, is:

$$L_{bs} = \left(\frac{1}{m_b}\right) * L_b \tag{63}$$

The factor m_b is a combination ratio:

$$m_b = m_1 * m_{b2} \tag{64}$$

Where, m_1, is the gear ratio from the unit output shaft to the final output shaft of the transmission, and m_{b2} is the ratio from bearing load cycles to the unit output shaft revolutions. m_{b2} can be found in table 3.

If one substitutes factor m_b , equation 63, into equation 62 a relation is obtained which will calculate gear life in output shaft

TABLE 3

Ratio Relating Bearing Load Cycles to

Unit Output Shaft Rotations

spiral bevel	single input	dual input
pinion	$\frac{N_g}{N_p}$	$\frac{N_g}{N_p}$
gear	1.0	1.0

planetary	non-stepped	stepped
planet	$\frac{R_r}{R_p}$	$\frac{R_r}{R_{pr}}$

rotations from the gear tooth load. The equation for the bearings becomes:

$$L_{bs10} = \left(\frac{1}{m_b}\right) * \left(\frac{C_b}{F_b}\right)^{p_b} \tag{65}$$

This equation gives the bearing life in terms of output rotations.

Component System Dynamic Capacities

The dynamic capacity of each component can now be expressed as an output torque. By taking the p th root of equation 31 and replacing the ratio of the component system capacity to the component equivalent load by the ratio of component system dynamic capacity to reduction output torque, the component system lives can be used to determine the component system dynamic capacities.

$$D_i = (L_{i10})^{(1/p_i)} * (T_o) \tag{66}$$

These dynamic capacities are in units of output torque and express the output torque of the reduction at which 90 percent of a set of similar components will survive for one million rotations.

Transmission Life

To calculate the life of the transmission, the probability of survival of the transmission is expressed as the product of the probabilities of survival of the components.

$$S_T = \prod_{i=1}^{n} S_i \qquad (67)$$

The reciprocal of the equation is:

$$\frac{1}{S_T} = \prod_{i=1}^{n} \left(\frac{1}{S_i}\right) \qquad (68)$$

Taking the natural logarithm of this equation:

$$\log\left(\frac{1}{S_T}\right) = \sum_{i=1}^{n} \log\left(\frac{1}{S_i}\right) \qquad (69)$$

Using the Weibull distribution equation relating life to probability of survival, equation 33, the preceding equation becomes:

$$\log\left(\frac{1}{S_T}\right) = \log\left(\frac{1}{0.9}\right) \sum_{i=1}^{n} \left(\frac{L_T}{L_{i10}}\right)^{e_i} \qquad (70)$$

In this equation L_T is the life of each component and of the entire transmission for a transmission reliabilty of S_T. This equation is not a strict Weibull relationship between transmission life and reliability. The equation would be a true Weibull distribution if all the Weibull exponents, e_i, were equal. This is not true since Weibull exponents for gears and bearings will differ from each other significantly. This equation can be solved for S_T as a function of the transmission life, L_T, and plotted on Weibull coordinates.

On this plot of percent probability of failure versus transmission, life a straight line can be fit to the model. Linear regression can be used to approximate the straight line. The range of this linear regression is for probability of suvival between fifty and ninety-five percent. The slope of the straight line approximation is the transmission Weibull exponent e_T . The transmission life, L_{T10}, is the life calculated from the straight line approximation at a reliability S_T=0.9. This L_{T10} life is the life of the transmission at the given output torque. The equation using the transmission life L_{T10} and Weibull exponent, e_T is:

$$\log\left(\frac{1}{S_T}\right) = \log\left(\frac{1}{0.9}\right)\left(\frac{L_T}{L_{T10}}\right)^{e_T} \tag{71}$$

Transmission Dynamic Capacity

The basic dynamic capacity for the transmission, D_T, is the output torque which will give a transmission life of one million output shaft rotations, at a reliabilty of 90 percent. Setting S_T=0.9 in equation 69 yields:

$$\log\left(\frac{1}{0.9}\right) = \log\left(\frac{1}{0.9}\right)\sum_{i=1}^{n}\left(\frac{L_T}{L_{i10}}\right)^{e_i} \tag{72}$$

By canceling terms the equation becomes:

$$1 = \sum_{i=1}^{n} \left(\frac{L_T}{L_{i10}}\right)^{e_i} \tag{73}$$

Expressing the Palmgren load-life model in terms of component system torques and lives:

$$L_{i10} = \left(\frac{D_i}{T_o}\right)^{p_i} \tag{74}$$

Substitute into equation 73

$$1 = \sum_{i=1}^{n} \left[\frac{D_T \;/\; T_o^{\;p_i}}{D_i \;/\; T_o^{\;p_i}}\right] \tag{75}$$

Cancel terms and rearrange:

$$1 = \sum_{i=1}^{n} \left(\frac{D_T}{D_i}\right)^{p_i} \tag{76}$$

This equation can be solved by iteration to obtain the transmission dynamic capactity, D_T.

To find the load life exponent, a series of 90 percent reliability lives of the transmission are calculated at output torques between 10 and 100 percent of the dynamic capacity. The lives are plotted against torque on a log versus log plot. this curve can be approximated by a straight line. Using a linear regression, the slope and value of the function at one million cycles can be found. The negative reciprocal of the slope is the load life exponent for the

transmission. The value of the function at one million cycles will be the dynamic capacity of the transmission corresponding to the load life exponent. With the values from the linear regression, The load life relation for the transmission is given by:

$$L_{T10} = \left(\frac{D_T}{T_o}\right)^{p_T} \qquad (77)$$

Where, D_T is the output torque for one million output rotations, p_T is the load-life exponent and L_{T10} is the 90 percent reliability life of the transmission.

PROGRAM USE

To use the program one must define the geometry of the transmission. One can run the program interactively or by batch file. To run the program interactively, one will have to answer the prompts (questions) with the proper information. If a mistake is made entering the information according to the prompts, all is not lost. After a series of questions, the value of the last few will be printed out. A prompt will ask if you wish to change any of the previous answers. If one answers yes, the program will return to the beginning of the section and then one can input the correct information.

The program will prompt the user with a list of eight types of transmissions which can be analyzed. The eight types of transmissions are shown in figure 15. Any one of these eight types can be analyzed. Once the type of transmission is chosen, the program will ask for information to define each gear unit making up the transmission. The inputs for spiral bevel gear units are asked for separately from the inputs for the planetary gear units.

The inputs required for the spiral bevel gear unit are divided into three main parts: the geometry of the gear mesh, the mounting of the bearings and gears, and the characteristics of the bearings. These three sets of inputs can be found in table 4, 5, and 6 respectively.

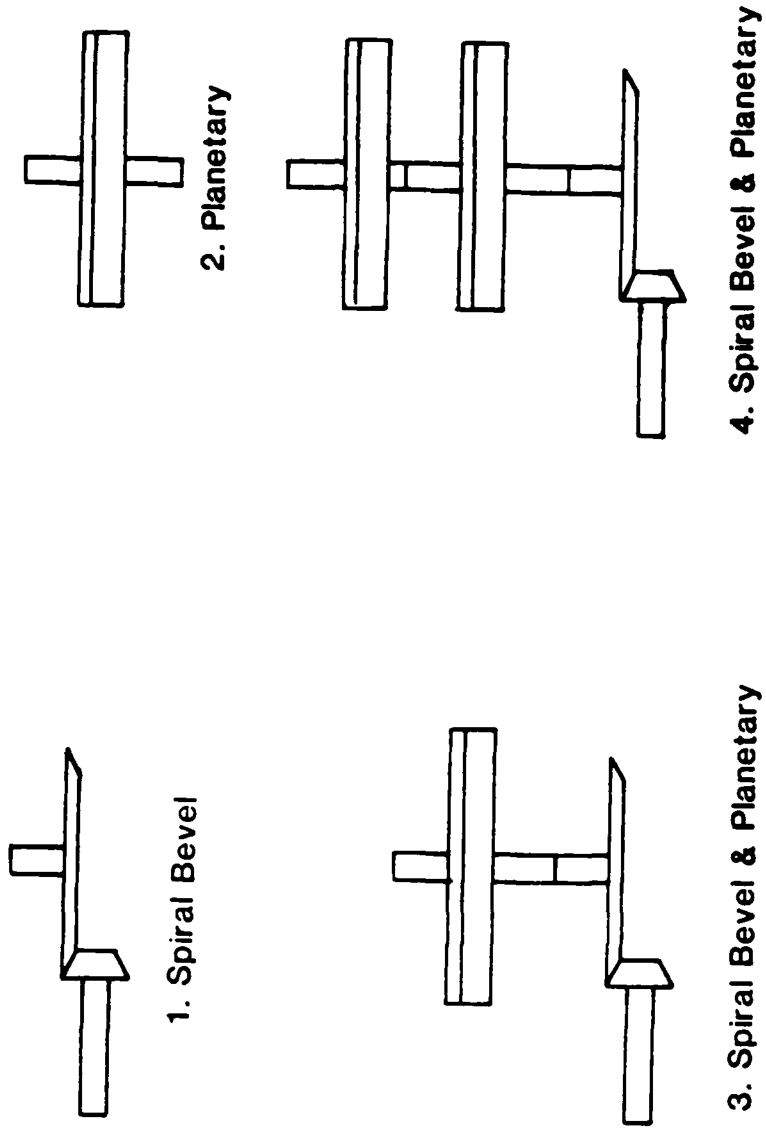


Figure 15

Helicopter Transmission Types

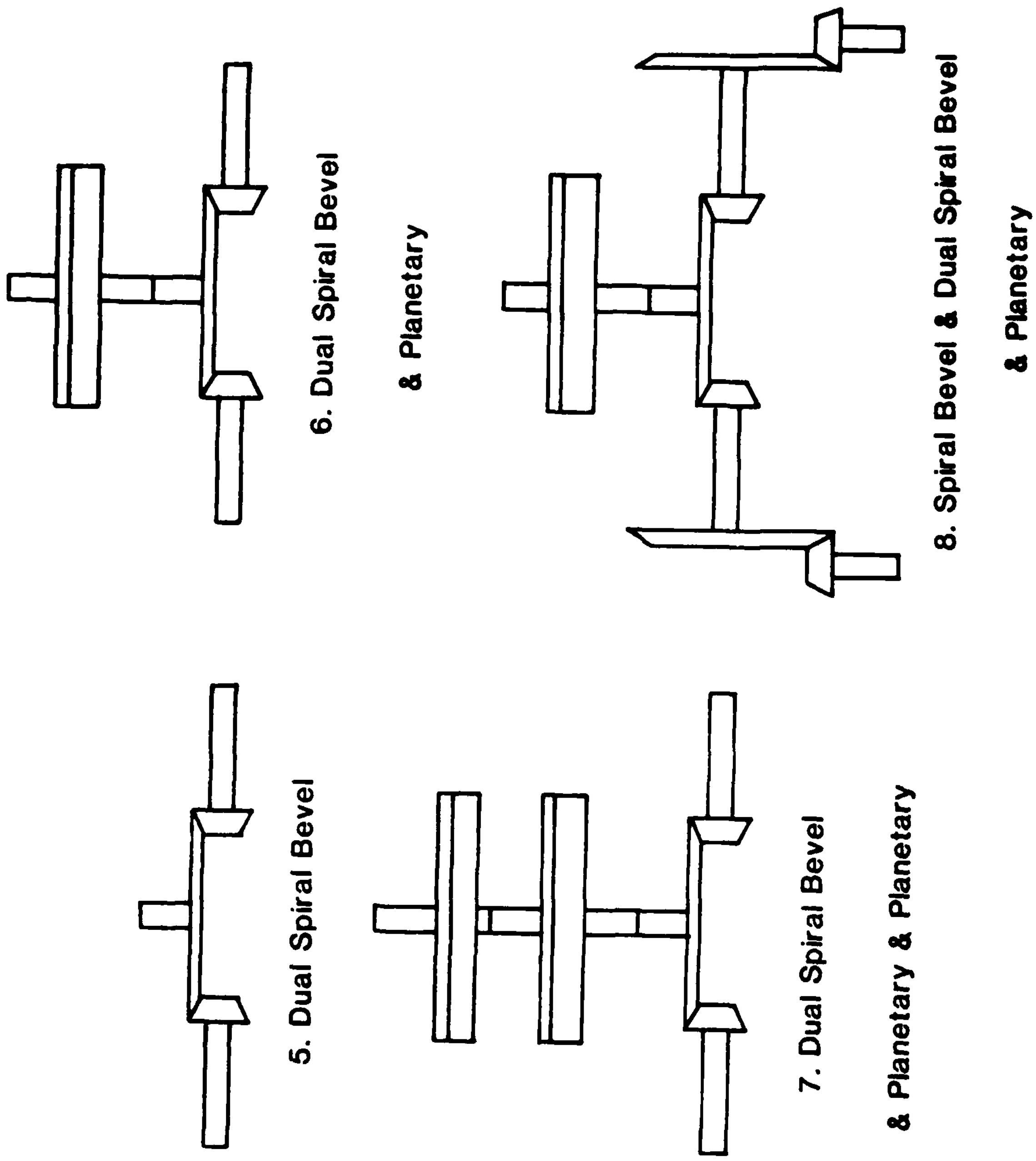


Figure 15 continued

Helicopter Transmission Types

TABLE 4

Inputs to Define the Geometry of the Spiral Bevel Gear Unit Gear Mesh

1. Number of teeth of the pinion
2. Number of teeth of the gear
3. The Cone distance of the gear mesh (in)
4. Face width of the gear mesh (in)
5. Normal pressure angle (deg)
6. Spiral angle of the gear mesh (deg)
7. Spiral hand of the gear mesh
8. Shaft angle between the pinion shaft centerline and the gear shaft centerline (deg)
9. Shaft angle between dual pinion inputs (deg) (dual pinion inputs only)
10. Input speed of pinion shaft (rpm)
11a. Input torque of the pinion shaft (lb-in)
11b. Input torque of the right pinion shaft (lb-in)
    Input torque of the left pinion shaft (lb-in)
    (dual pinion inputs only)
12. Direction of input torque
13. Gear mesh material constant
14. Gear mesh Weibull exponent
15. Gear mesh Load-Life exponent

TABLE 5

Inputs to Define the Mounting of the Spiral Bevel Gear Unit Bearings and Gears

1. The case of mounting - either straddle or overhung mounting
2. Distance A - Gear to bearing closest to the gear mesh apex
3. Distance B - Gear to bearing furthest from the gear mesh apex
4. The bearing which takes the thrust load

TABLE 6

Inputs to Define the Characteristics of the

Spiral Bevel Gear Unit Bearings

The bearings can be of the following types:

1. Single row ball bearings
2. Double row ball bearings
3. Single row roller bearings
4. Double row roller bearings
5. Single row tapered roller bearings
6. Double row tapered roller bearings

For types 1 and 2 - Single and Double row ball bearings the inputs required are :

1. Number of rolling elements in the bearing
2. Diameter of the rolling elements in the bearing (in)
3. Bearing contact angle (deg)
4. Basic dynamic capacity (lbs)
5. Rotational factor (inner race or outer race rotation)
6. Weibull exponent
7. Life adjustment factor

For types 3 and 4 -Single and Double row roller bearings the inputs required are :

1. Basic dynamic capacity (lbs)
2. Rotational factor (inner race or outer race rotation)
3. Weibull exponent
4. Life adjustment factor

For types 5 and 6 -Single and Double row tapered roller bearings the inputs required are :

1. Thrust ratio
2. Basic dynamic capacity (lbs)
3. Weibull exponent
4. Life adjustment factor

In the planetary gear unit, the inputs will be for either an unstepped planetary or a stepped planetary. The stepped planetary gear unit will require extra inputs to define the stepped planet gears. Inputs for a planetary gear unit are found in table 7.

In the program, the spiral bevel gear unit and planetary gear unit analysis are done in separate parts. The method of analysis is the same in both parts. First the geometry of the gears is completed from the information given and the geometric relations. Next the loads on each component of the unit are calculated. The life of the component is calculated from the load on the component and the load cycle ratio of the component. The dynamic capacity is then calculated for each component. From the calculated lives of the components, the life and the Weibull exponent of the transmission is found by iteration. The program next figures a series of transmission lives verses output torques between 10 and 100 percent transmission dynamic capacity. Using a linear approximation of the output load verses life of the transmission, the transmission dynamic capacity and load-life exponent is found. Figure 16 is a basic flow chart of the program. Appendix C contains the computer listing for the program.

In the output of the program one will find the complete dimensions of the gear meshes and the forces on the components. Also the component system lives and dynamic capacities are in the output. The transmission life and dynamic capacity are the final results produced by the program. Table 8 lists the format of the transmission analysis results.

TABLE 7

Inputs to Define the Geometry of the

Planetary Gear Unit

1. Basic dynamic capacity of planet bearing (lbs)
2. Rotational factor (inner race or outer race rotation)
3. Weibull exponent for the planet bearing
4. Load-life exponent for the planet bearing
5. Life adjustment factor for the planet bearing
6. Number of planet bearings
7. Is the diametral pitch the same for the sun and ring gear ?
   When the pitches are the same :
   7a. Diametral pitch of the meshes
   When the pitches are different :
   7b. Diametral pitch of the sun-planet mesh
   Diametral pitch of the ring-planet mesh
8. Is the pressure angle the same for the sun and ring gear ?
   When the pressure angle is the same :
   8a. Pressure angle of the meshes (deg)
   When the pressure angles are different :
   8b. Pressure angle of the sun-planet mesh (deg)
   Pressure angle of the ring-planet mesh (deg)
9. Number of teeth on the sun gear
10. Face width of the sun gear (in)
11. Weibull exponent for the sun-planet mesh
12. Load-life exponent for the sun-planet mesh
13. Material constant for the sun-planet mesh
14. Does the transmission have stepped planet gears ?
    When the planets are unstepped :
    14a. Number of teeth on the unstepped planet gear
    When the planets are stepped :
    14b. Number of teeth on planet gear meshed with sun gear
    Number of teeth on planet gear meshed with ring gear
15. Number of teeth on the ring gear
16. Face width of the ring-planet mesh (in)
17. Weibull exponent of the ring-planet mesh
18. Load-life exponent of the ring-planet mesh
19. Input torque (lb-in)
20. Input speed (rpm)

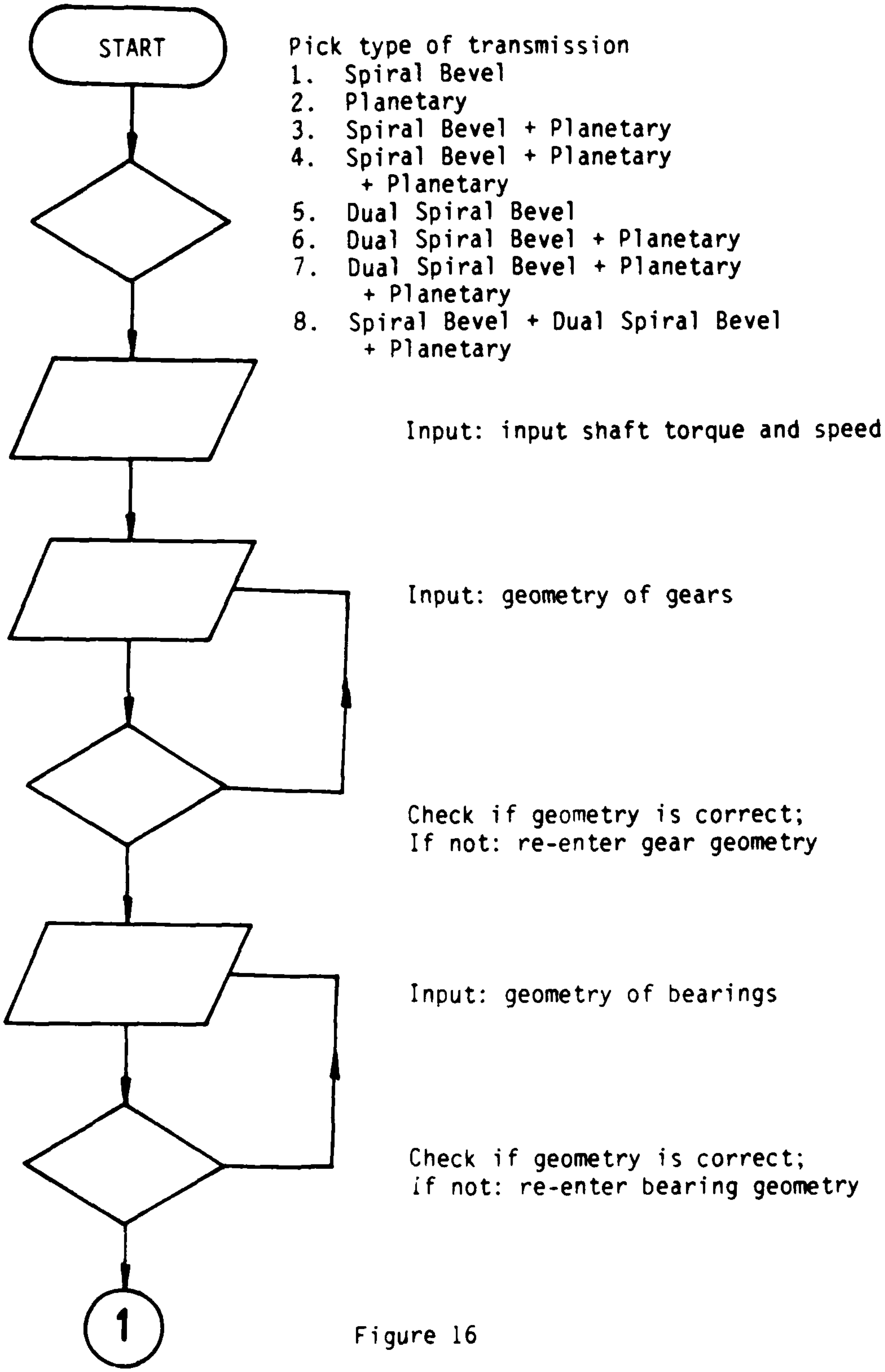


Figure 16

Computer Program Flow Chart

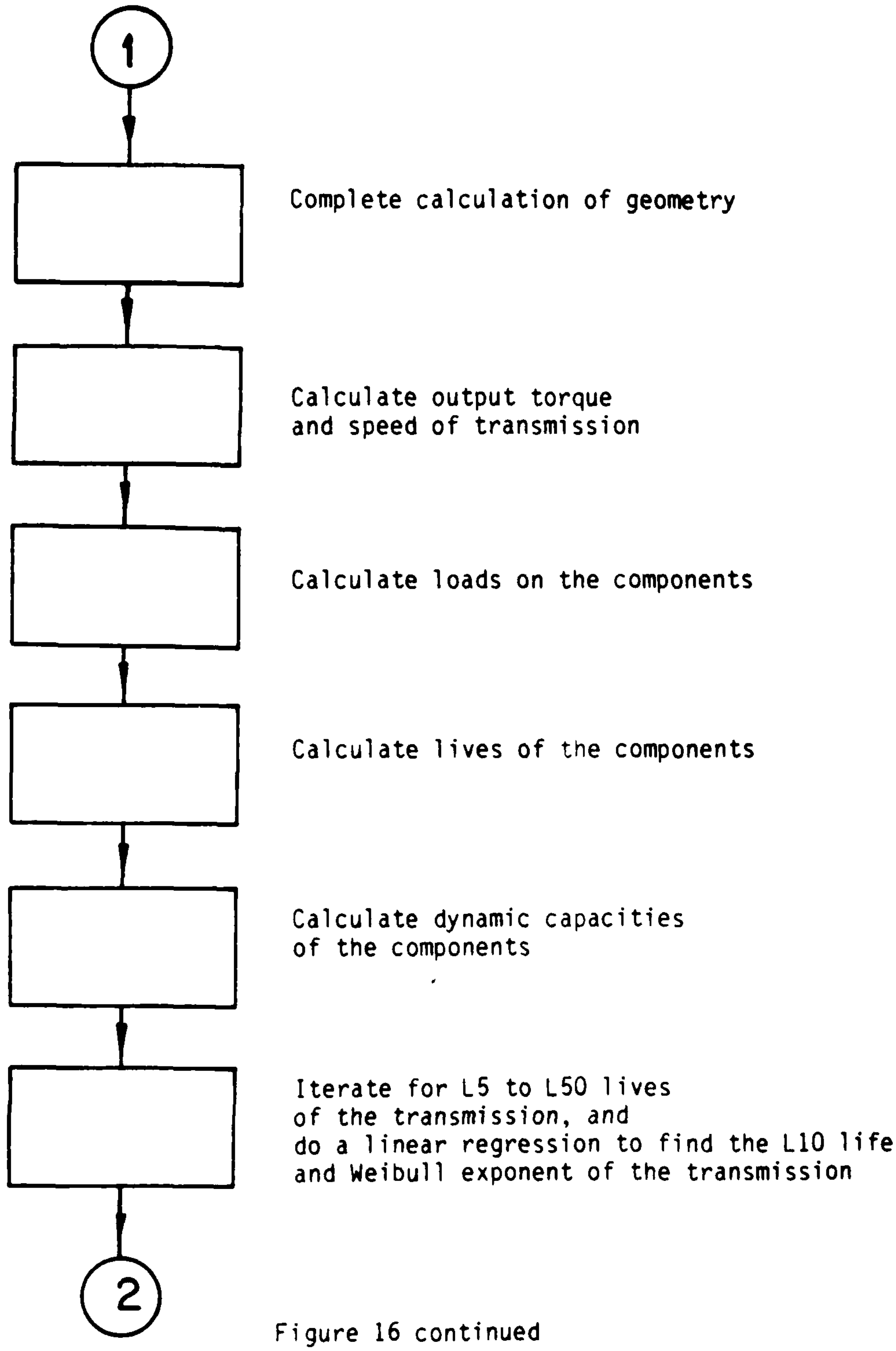


Figure 16 continued

Computer Program Flow Chart

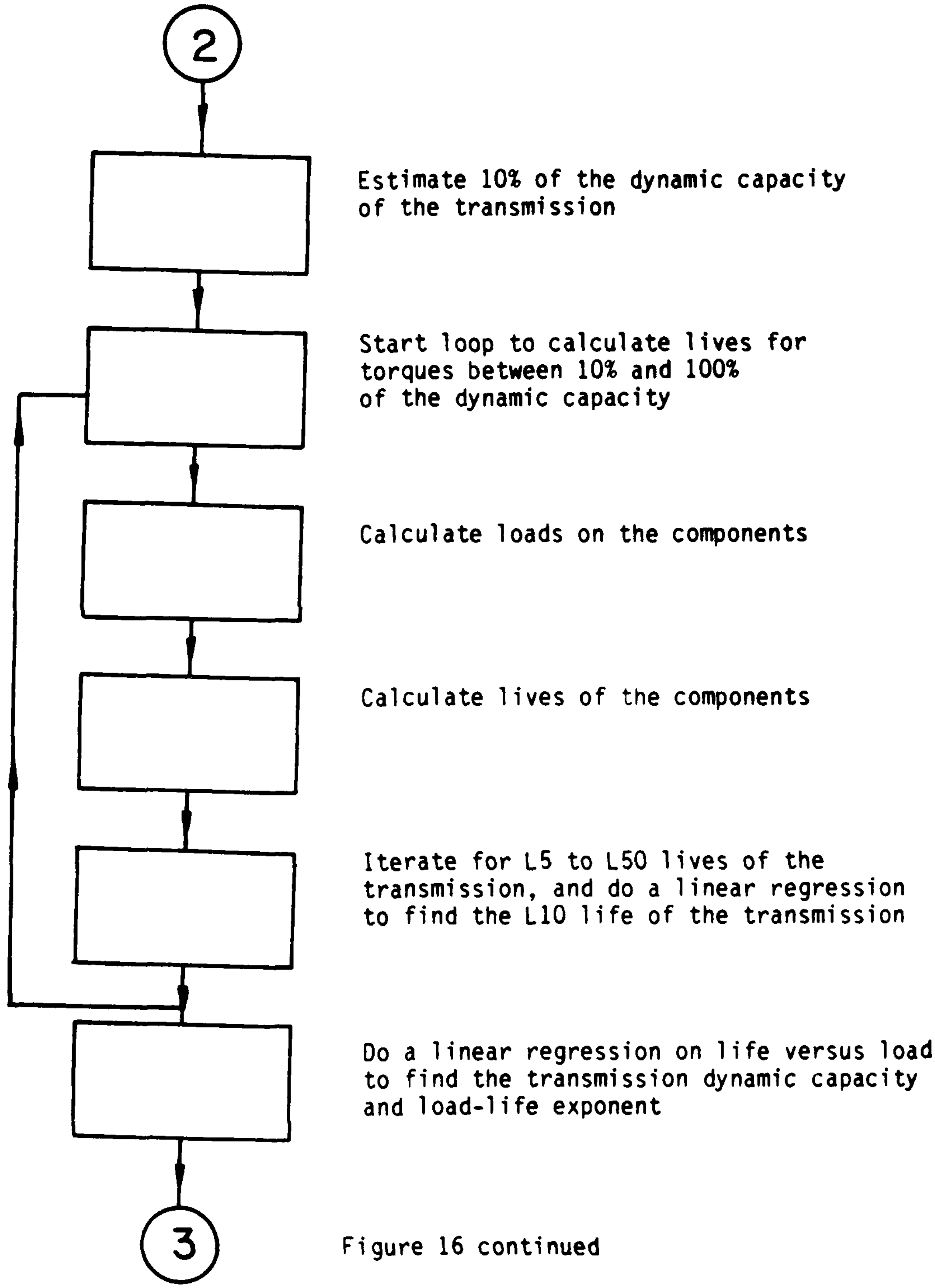


Figure 16 continued

Computer Program Flow Chart

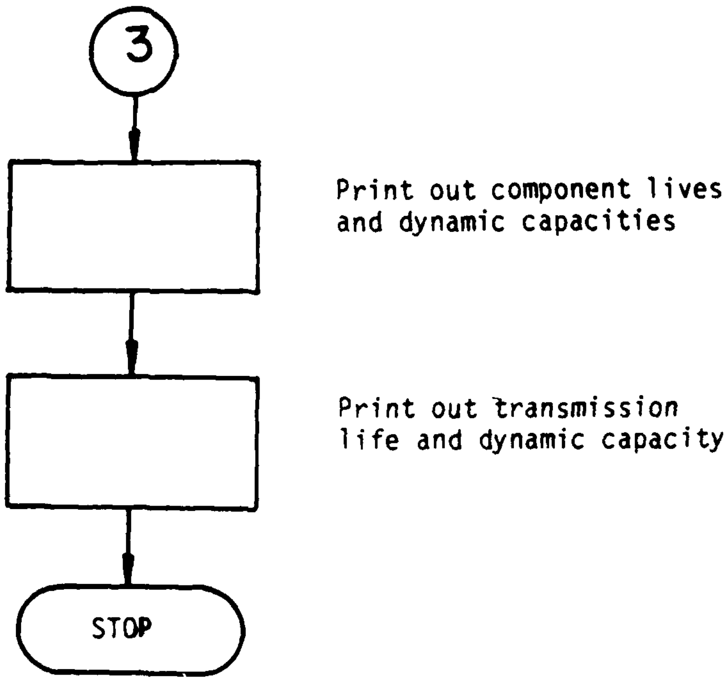


Figure 16 continued

Computer Program Flow Chart

TABLE 8

Output of the Program

For each gear unit the following will be output:

1. The gear mesh geometry
2. The gear mounting geometry
3. The forces on the gears and bearings

For each component the following will be output:

1. Component system dynamic capacity
2. Component system load-life exponent
3. Component system life in output shaft rotations
4. Component system life in hours
5. Component system Weibull exponent

For the transmission the following will be output

1. Transmission system dynamic capacity
2. Transmission system load-life exponent
3. Transmission system life in output shaft rotations
4. Transmission system life in hours
5. Transmission system Weibull exponent

NUMERICAL EXAMPLE

In the design of a transmission the components are sized from the power transfer requirement. The initial design does not consider the effects of the components on one another. The initial design contains some overdesigned and weak parts. One can change the parameters on the overdesigned and weak components to see the overall effect in the transmission.

In this example, the transmission being designed is a 320 horsepower single input helicopter transmission. The input speed is 6180 rpm and the output speed is 354 rpm. The L_{10} life of the transmission is to be approximately 3500 hours at the rated power level.

The layout chosen for this transmission is a spiral bevel unit followed by an unstepped planetary unit, figure 17. The spiral bevel unit will produce a gear reduction of 3.736 : 1. The input torque will be transferred through 95 degrees from an approximately horizontal input to a vertical output shaft. Table 9 lists the geometry of the spiral bevel unit. The planetary unit will produce a gear reduction of 4.66 : 1 along the output shaft. Table 10 lists the geometry of the planetary unit. Appendix A shows how the input is entered into the program for this original design.

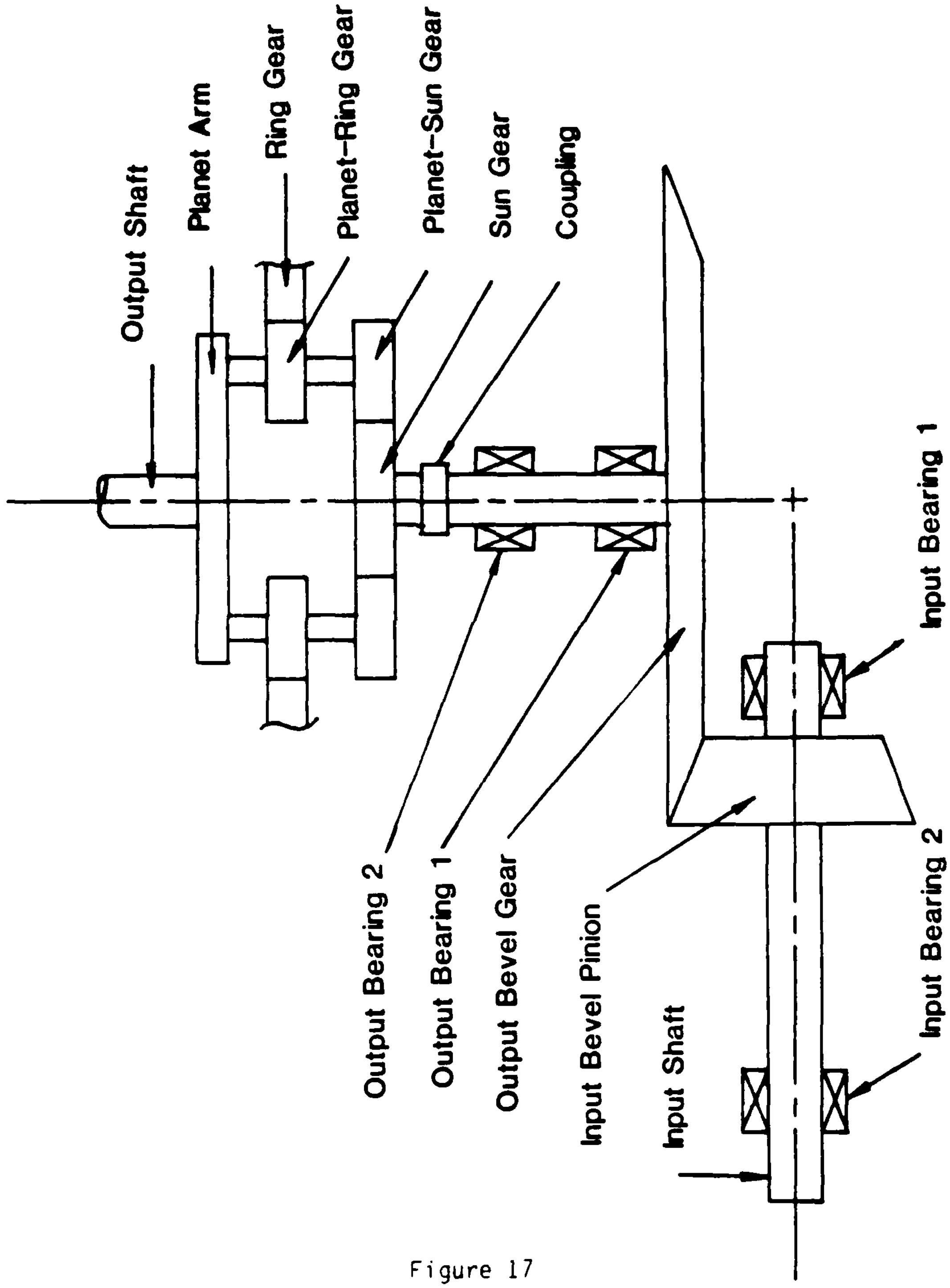


Figure 17

Helicopter Transmission

TABLE 9

Spiral Bevel Gear Unit Input For Numerical Example

Gear mesh geometry	
Number of teeth on the pinion	19
Number of teeth on the gear	71
Cone distance	5.199 in.
Normal pressure angle	20. deg.
Face width	1.8 in.
Spiral angle	25 deg.
Clockwise rotation	
Left hand spiral	
Shaft angle	95 deg.
Gear mesh material constant	35000. psi
Gear mesh weibull exponent	2.5
Gear mesh load-life expoent	4.3
Pinion mounting	
Straddle mount with bearing 2 taking thrust load	
Distance A	1.3 in.
Distance B	2.5 in.
Pinion bearing 1	
Single row roller bearing	
Basic dynamic capacity	14000. lbs.
Rotational factor (inner race rotation)	1.0
Weibull exponent	1.5
Bearing life adjustment factor	2.5
Pinion bearing 2	
Double row ball bearing	
Number of rolling elements	14
Diameter of rolling elements	.5625 in.
Contact angle	35 deg.
Basic dynamic capacity	25000. lbs
Rotaional factor (inner race rotation)	1.0
Weibull exponent	1.5
Bearing life adjustment factor	2.5
Gear mounting	
Overhung mount with bearing 2 taking thrust load	
Distance A	0.9 in.
Distance B	2.6 in.

Table 9 Continued

Gear bearing 1	
Single row roller bearing	
Basic dynamic capacity	20000. lbs
Rotation factor (inner race rotation)	1.0
Weibull exponent	1.5
Bearing life adjustment factor	2.5
Gear bearing 2	
Double row ball bearing	
Number of rolling elements	25
Diameter of rolling elements	.375 in.
Contact angle	27 deg.
Basic dynamic capacity	19076 lbs
Rotaional factor (inner race rotation)	1.0
Weibull exponent	1.5
Bearing life adjustment factor	2.5

TABLE 10

Planetary Gear Unit Input For Numerical Example

Basic dynamic capacity of bearings	20895 lbs.
Bearing Life adjustment factor	2.5
Rotational factor (inner race rotation)	1.0
Weibull exponent	1.5
Load-life exponent	3.33
Number of planet bearings	3
Number of teeth on sun gear	27
Number of teeth on planet-sun gear	35
Number of teeth on planet-ring gear	35
Number of teeth on ring gear	99
Diametral pitch of sun gear mesh	8.8710
Diametral pitch of ring gear mesh	9.1429
Pressure angle of sun gear mesh	20 deg.
Pressure angle of ring gear mesh	14.0682 deg.
Face width of sun gear mesh	3.178 in.
Face width of ring gear mesh	2.540 in.
Weibull exponent of sun gear mesh	2.5
Weibull exponent of ring gear mesh	2.5
Load-life exponent of sun gear mesh	4.3
Load-life exponent of ring gear mesh	4.3
Material constant of sun gear mesh	20800. psi
Material constant of ring gear mesh	20800. psi

The program was run with the geometry described in table 9 and 10. The output of the program can be found in appendix B. The program first calculates the loading on each component in the transmission. This intermediate step of calculating the life of the components is useful to a designer. If the designer changes the geometry of the transmission the loads on the components will change. The change in loading of the component will change the life of the component without changing the dynamic capacities of the components.

After the intermediate step of calculating the loads, the program computes the life of each component. The dynamic capacity of each component is calculated next. The life and Weibull exponent is then calculated for the spiral bevel unit, planetary unit, and the total transmission. Finally the dynamic capacity and load life exponent is calculated for the spiral bevel unit, planetary unit, and the total transmission.

The intermediate calculation of life and dynamic capacity of the spiral bevel unit and the planetary unit are valuable since a change within one unit will not effect the components in the other unit. Therefore the effects of design change within a unit are readily observed.

The values of the total transmission life and dynamic capacity will help the designer determine the critical elements in the transmission by comparing the values for the transmission to the life and dynamic capacity of each unit. Table 11 shows the values of dynamic capacity, load-life exponent, life in output rotations, life in hours, and Weibull exponent for the initial design. By checking the values of

Table 11

Life and Dynamic Capacity of Transmission

Design 1

Component	dynamic capacity	load-life exponent	life in output rotations	life in hours	Weibull exponent
Spiral Bevel Unit	77,327	4.02	17*10E6	797	2.27
Input Pinion	79,215	4.3	20*10E6	957	2.5
Input Bearing 1	194,082	3.3	194*10E6	9,140	1.5
Input Bearing 2	446,909	3.0	1.469*10E9	69,124	1.5
Output Gear	95,272	4.3	44*10E6	2,111	2.5
Output Bearing 1	139,135	3.3	64*10E6	3,047	1.5
Output Bearing 2	163,966	3.0	72*10E6	3,413	1.5
Planetary Unit	136,760	3.43	70*10E6	3,370	1.509
Planet Bearing	175,807	3.3	147*10E6	6,929	1.5
Sun Gear	174,807	4.3	605*10E6	28,474	2.5
Ring Gear	3,970,348	4.3	415*10E12	19*10E9	2.5
Planet-Ring Gear	233,424	4.3	2.122*10E9	99,815	2.5
Planet-Sun Gear	4,433,816	4.3	668*10E12	31*10E9	2.5
Total Transmission	76,841	3.966	16*E6	758	2.2

the spiral bevel unit and planetary unit against the values for the total transmission, it can be seen that the spiral bevel unit values are very close to the transmission values. This is also illustrated in figure 18. The spiral bevel unit dominates the life and dynamic capacity of the total transmission. Therefore it is the weakest part of the transmission. By further examination it can be seen that the life and dynamic capacity of the spiral bevel unit is dominated by the input pinion and output gear. The value of these components are much lower than any other component in the system, therefore a redesign of the gear mesh would be recommended.

In this example the size of the spiral bevel gear mesh was increased. The size of the cone distance, A_0, was increased from 5.199 inches to 8.5 inches, and the face width, f, was increased from 1.8 inches to 3.5 inches. This redesign causes an increase in spiral bevel unit life of 400 percent and an increase in transmission life of 300 percent. The results of this redesign are shown in table 12. The life verses probability of failure graph for this case is shown in figure 19.

The life of the transmission is still less than the life required in the specifications. Since the life of the spiral bevel unit and planetary unit are about equal, the lives of both units will have to be increased. In the spiral bevel unit, the output bearings have the lowest life. In this case the dynamic capacity of the bearings are increased. For the planetary unit the planet bearings have the lowest life. There are two choices to increase the life of the planet bearing, either increase the number of planet bearings or

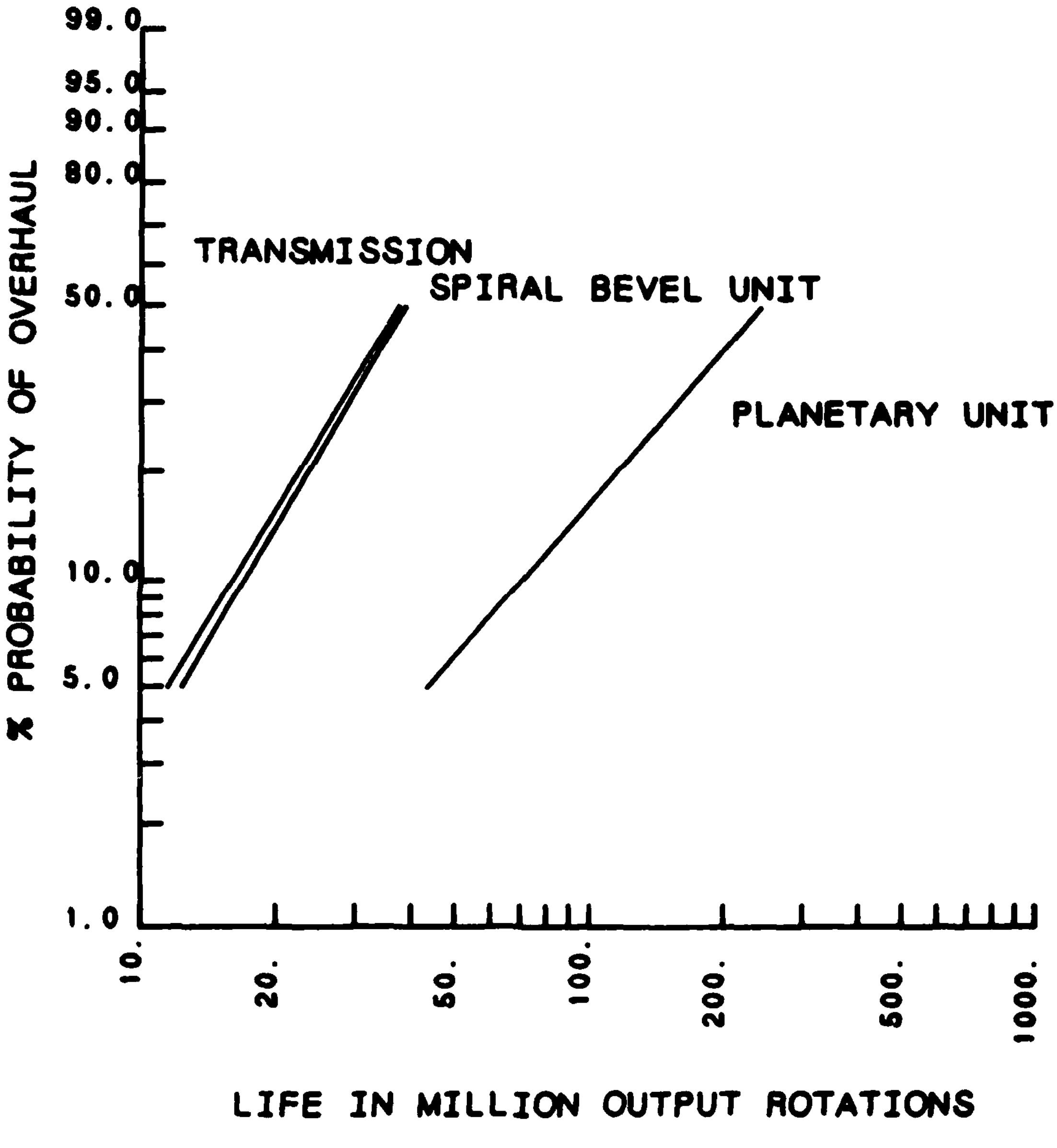


Figure 18

Life Versus Probability of Failure Design 1

Table 12

Life and Dynamic Capacity of Transmission

Re-Design 1

Component	dynamic capacity	load-life exponent	life in output rotations	life in hours	Weibull exponent
Spiral Bevel Unit	156,406	3.15	78*10E6	3,631	1.5
Input Pinion	379,730	4.3	1.720*10E10	81*10E4	2.5
Input Bearing 1	292,227	3.3	750*10E6	35,278	1.5
Input Bearing 2	707,016	3.0	5.819*10E9	273,692	1.5
Output Gear	456,416	4.3	3.794*10E10	18*10E5	2.5
Output Bearing 1	177,080	3.3	143*10E6	6,754	1.5
Output Bearing 2	191,072	3.0	114*10E6	5,402	1.5
Planetary Unit	136,760	3.43	70*10E6	3,370	1.50
Planet Bearing	175,807	3.3	147*10E6	6,929	1.5
Sun Gear	174,807	4.3	605*10E6	28,474	2.5
Ring Gear	3,970,348	4.3	415*10E12	19*10E9	2.5
Planet-Ring Gear	233,424	4.3	2.122*10E9	99,815	2.5
Planet-Sun Gear	4,433,816	4.3	668*10E12	31*10E9	2.5
Total Transmission	125,832	3.31	47*10E6	2,199	1.5

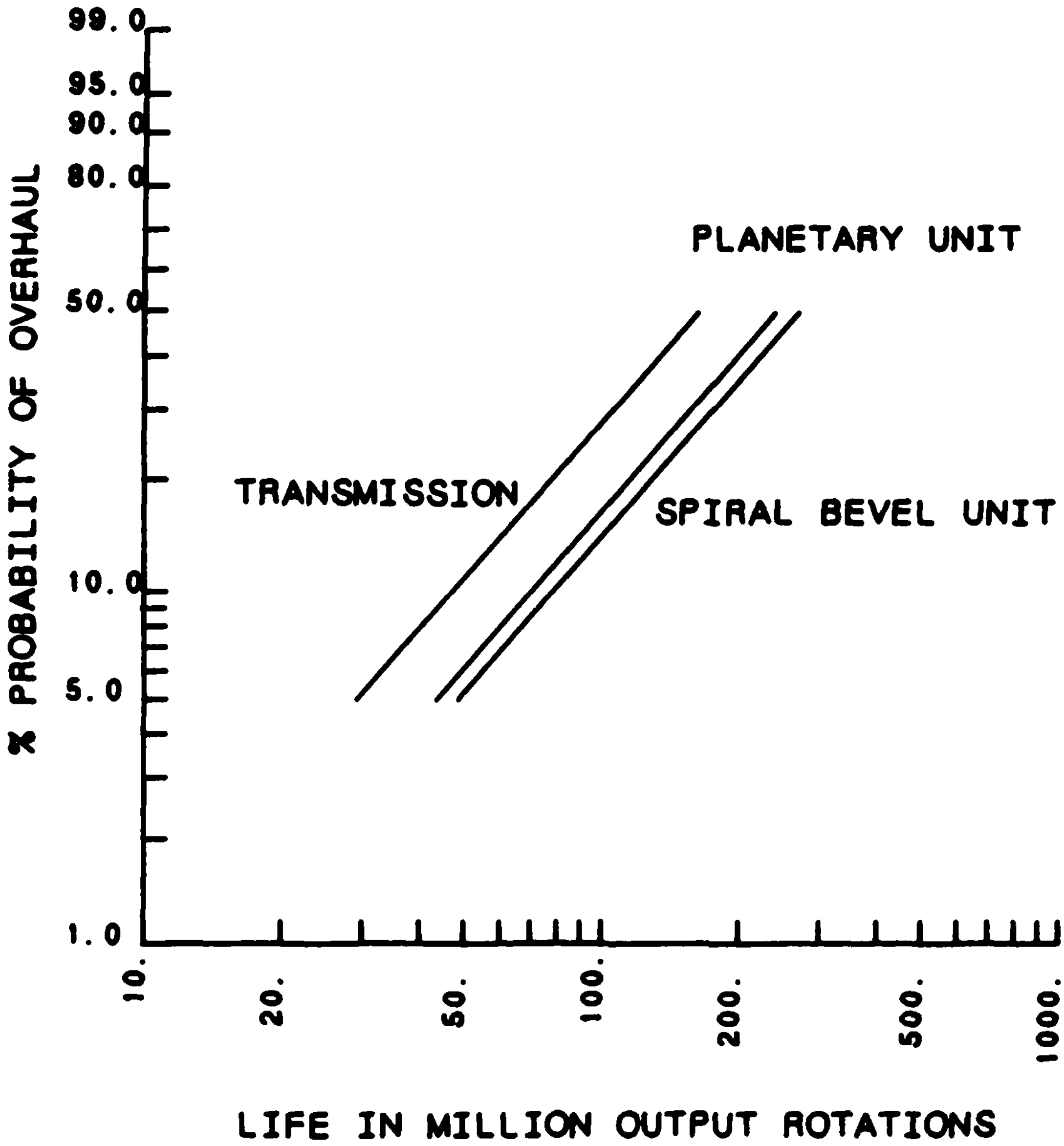


Figure 19

Life Versus Probability of Failure Re-Design 1

increase the dynamic capacity of the bearings. In this case the number of bearings is increased. The life of the bearings will increase because the load on each bearing will be lower. This also increases the life of the other components in the planetary since the loads transmitted by each planet gear will be lower.

The results of this redesign are shown in table 13. The life verses probability of failure graph for this case is shown in figure 20. The modifications doubled the life of each unit. The life of the total transmission increased to 4500 hours which is above the design requirement of 3500 hours. By examining the Weibull and load-life exponents one can see that the design is dominated by the life of the bearings. The Weibull and load-life exponents are very close to the most common exponent values of bearings. This indicates that the life and dynamic capacity of the transmission are dominated by the bearings. This is a good test to find which components dominate the life of the transmission or any unit in the transmission.

The results of each following design run will give a great deal of information on which design changes can be based. These design changes will allow the designer to approach an optimal transmission design.

Table 13

Life and Dynamic Capacity of Transmission

Re-Design 2

Component	dynamic capacity	load-life exponent	life in output rotations	life in hours	Weibull exponent
Spiral Bevel Unit	190,350	3.19	153*10E6	7,208	1.5
Input Pinion	379,730	4.3	1.720*10E10	81*10E4	2.5
Input Bearing 1	292,227	3.3	750*10E6	35,278	1.5
Input Bearing 2	707,016	3.0	5.819*10E9	273,692	1.5
Output Gear	456,416	4.3	3.794*10E10	18*10E5	2.5
Output Bearing 1	212,497	3.3	262*10E6	12,328	1.5
Output Bearing 2	250,409	3.0	258*10E6	12,159	1.5
Planetary Unit	171,938	3.43	152*10E6	7,158	1.50
Planet Bearing	234,410	3.3	384*10E6	18,077	1.5
Sun Gear	217,442	4.3	1.564*10E9	73,578	2.5
Ring Gear	4,951,214	4.3	1.070*10E15	50*10E9	2.5
Planet-Ring Gear	311,232	4.3	7.312*10E9	343,900	2.5
Planet-Sun Gear	5,911,754	4.3	2.300*10E15	11*10E9	2.5
Total Transmission	156,765	3.32	96*10E6	4,526	1.5

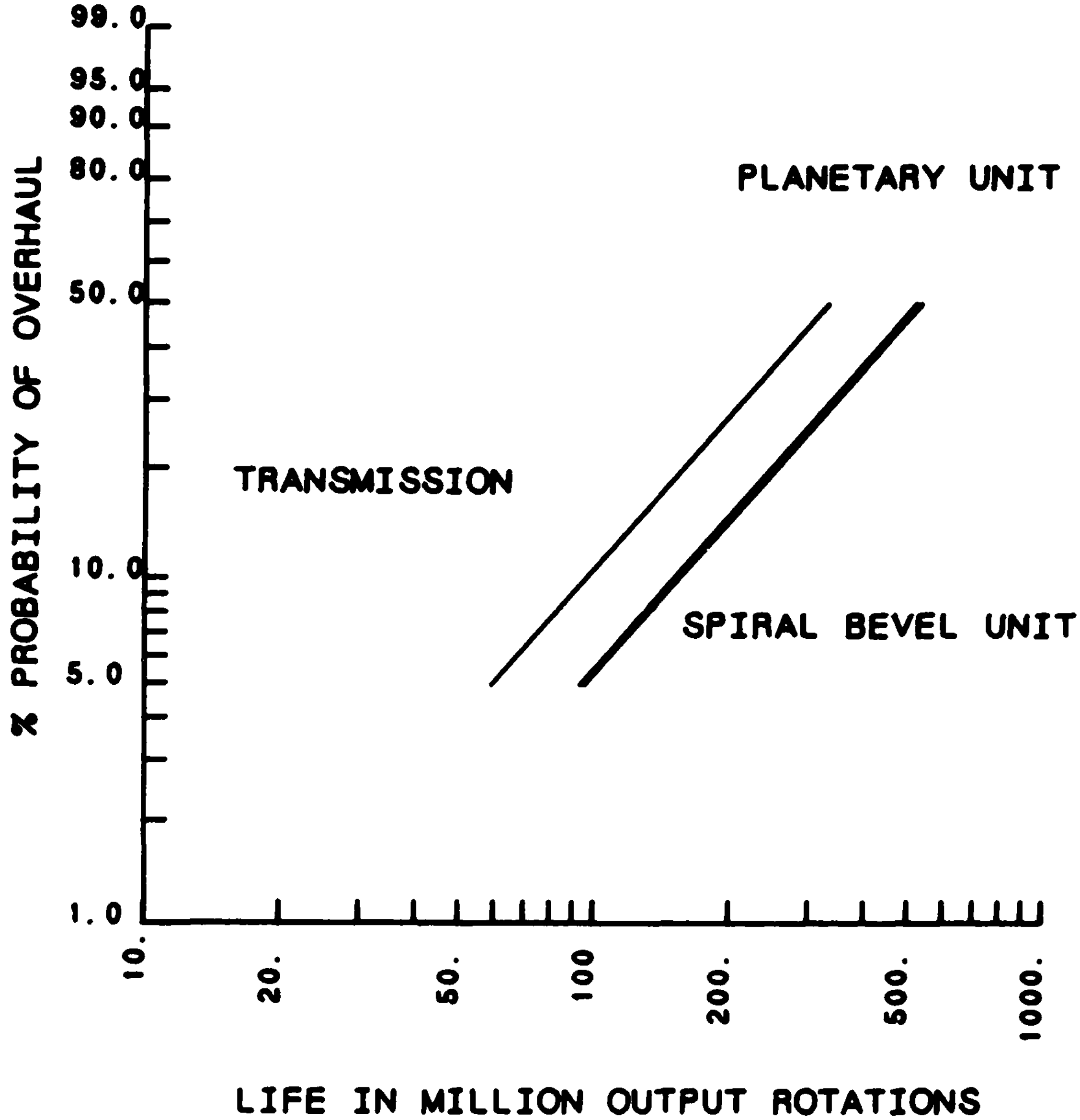


Figure 20

Life Versus Probability of Failure Re-Design 2

DISCUSSION OF RESULTS

This computer program was developed to model the life and reliability of helicopter transmissions. The calculation of the life of a transmission is based on a strict series probability law. The strict series probability law states that the probability of survival of a transmission is the product of the probabilities of survival of all the components. The relationship between the probability of survival of a component and its life is the two parameter Weibull distribution. The resulting reliability model for the transmission is also a two parameter Weibull distribution.

The computer program is written in a modular form to model many different types of transmissions. In addition to results for the overall transmission, intermediate results for modules of the transmission are given.

Input to the computer program is to be given in an interactive format. The program prompts the user with questions which ask for the parameters required to describe the transmission. In this interactive format, a screen by screen review of the input data is provided to the user. If any data on the screen is incorrect, the user may return to the input stream at a point just prior to this screen to input this data correctly. If more than one design is to be

modeled at a time, an input data file may be used to speed up the use of the program. The user can change one parameter in a data file and quickly run the program again to determine the effects of this change on the components and the transmission.

The output of the computer program gives a complete overview of the transmission analysis. The geometry of the components entered into the program and the geometry calculated for the components are both printed out. Lives and dynamic capacities of the components are printed out in terms of component cycles and loads and in terms of system cycles and load. Each result listed in the output includes a title and the proper units.

By using the program in a systematic manner, a user can approach an optimal design. An example of this use is given in the proceeding chapter to illustrate the use of the program. Sample input and output listings are included in the first two appendices. The third appendix is a listing of the fortran source code for the program.

SUMMARY OF RESULTS

This report describes a computer simulation program which models the life and reliability of a helicopter transmission. The computer program uses the lives and reliabilities of the individual bearings and gears in the transmission to compute the life and reliability of the transmission. This model is a strict series probability model which is based on the pitting fatigue life and reliability models for the components of the transmission.

In this program, a modular approach is used in which the force and motion analyses of the transmission are separated from the life and reliability analyses. The dynamic capacity models are also separated algebraically from the prior calculations. In this way, the calculations can be performed sequentially and the complexity and diversity of the analyzed transmissions can be increased greatly.

The computer program can simulate a number of transmission configurations built up from spiral bevel gear units, a dual spiral bevel gear unit and stepped or unstepped planetary gear units. The eight transmission configurations analyzed by the program are:

1) a spiral bevel reduction,

2) a planetary reduction,

3) a spiral bevel reduction followed by a planetary reduction,

4) a spiral bevel reduction followed by two planetary reductions in series,

5) a dual spiral bevel reduction with two input pinions of equal size,

6) a dual spiral bevel unit followed by a single planetary reduction,

7) a dual spiral bevel unit followed by two planetary reductions in series, and

8) a dual spiral bevel unit followed by a planetary reduction and proceeded by two spiral bevel input reductions.

The program allows any planetary unit to be composed of stepped or unstepped planets. It can simulate transmission designs at different power levels and load duty cycles. The program can calculate the lives and dynamic capacities of a single unit or the transmission as a whole.

This report includes a development of the theory behind the program model, a listing of the program in fortran source code and examples illustrating the use of the program.

APPENDIX A

PROGRAM INPUT

```
 HELICOPTER TRANSMISSION ANALYSIS
 ENTER THE NUMBER FOR THE TYPE OF TRANSMISSION
 SPIRAL BEVEL.................................1
 PLANETARY....................................2
 SPIRAL BEVEL + PLANETARY.....................3
 SPIRAL BEVEL + PLANETARY + PLANETARY.........4
 DUAL SPIRAL BEVEL............................5
 DUAL SPIRAL BEVEL + PLANETARY................6
 DUAL SPIRAL BEVEL + PLANETARY + PLANETARY......7
 SPIRAL BEVEL + DUAL SPIRAL BEVEL + PLANETARY...8

3
WHAT IS THE INPUT TORQUE OF THE TRANSMISSION
3262
WHAT IS THE INPUT SPEED OF THE TRANSMISSION
6180


 SPIRAL BEVEL GEAR UNIT INPUTS


DO YOU WISH TO USE A DATA SET
ANSWER YES OR NO
NO
WHAT IS THE NUMBER OF TEETH ON THE PINION
19
WHAT IS THE NUMBER OF TEETH OF THE GEAR
71
WHAT IS THE CONE DISTANCE OF THE GEAR MESH
5.1999
WHAT IS THE NORMAL PRESURE ANGLE (DEG)
20
WHAT IS THE FACE WIDTH OF THE GEAR MESH (IN)
1.8
WHAT IS THE SPIRAL ANGLE OF THE PINION
25
```

```
WHAT IS THE DIRECTION OF PINION ROTATION
LOOKING FROM THE APEX TO THE FACE OF THE PINION
(COUNTERCLOCKWISE INPUT 1)
(CLOCKWISE INPUT -1 )
-1
WHAT IS THE HAND OF THE SPIRAL ANGLE ON THE PINION
(RIGHT INPUT 1)
(LEFT INPUT -1)
-1
WHAT IS THE SHAFT ANGLE BETWEEN THE CENTER LINE OF THE
PINION SHAFT AND THE CENTER LINE OF THE GEAR SHAFT (DEG)
95
WHAT IS THE MESH MATERIAL CONSTANT (PSI)
35000
WHAT IS THE MESH WEIBULL EXPONENT
2.5
WHAT IS THE MESH LOAD-LIFE FACTOR
4.3
WHAT IS THE LIFE ADJUSTMENT FACTOR OF THE BEARINGS
2.5

 NUMBER OF TEETH ON PINION                                  19.000
 NUMBER OF TEETH ON GEAR                                    71.000
 CONE DISTANCE                                             5.19990
 NORMAL PRESSURE ANGLE                                    20.00000
 FACE WIDTH                                                1.80000
 SPIRAL ANGLE                                             25.00000
 DIRECTION OF ROTATION                                    -1.00000
 HAND OF SPIRAL                                           -1.00000
 SHAFT ANGLE BETWEEN PINION AND GEAR                      95.00000
 GEAR MESH MATERIAL CONSTANT                           35000.00000
 WEIBULL EXPONENT                                          2.50000
 MESH LOAD LIFE FACTOR                                     4.30000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0
PINION MOUNTING
WHICH CASE OF BEARING PLACEMENT IS BEING USED
CASE # 1
BEARING-------GEAR----------BEARING
  #1                          #2
*------A--------*------B-------*

CASE # 2
GEAR---------BEARING--------BEARING
               #1             #2
*------A--------*
#---------------B--------------#
1
WHICH BEARING CARRIES THE THRUST LOAD
BEARING #1 OR BEARING #2
2
```

```
ENTER DISTANCE A - DISTANCE FROM * TO * (IN)
1.3
ENTER DISTANCE B - DISTANCE FROM * TO * (IN)
2.5

CASE NUMBER                               1
BEARING TAKING THE THRUST LOAD            2
DISTANCE A                                          1.3000
DISTANCE B                                          2.5000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0
PINION BEARING #1
TYPE OF BEARING - ENTER NUMBER
  1 - SINGLE ROW BALL BEARING
  2 - DOUBLE ROW BALL BEARING
  3 - SINGLE ROW ROLLER BEARING
  4 - DOUBLE ROW ROLLER BEARING
  5 - SINGLE ROW TAPERED ROLLER BEARING
  6 - DOUBLE ROW TAPERED ROLLER BEARING
3
ENTER THE BASIC DYNAMIC CAPACITY OF BEARING
14000
ENTER THE ROTATION FACTOR
1.0 FOR INNER RACE ROTATION
1.2 FOR OUTER RACE ROTATION
1.0
WHAT IS THE WEIBULL EXPONENTFOR THE BEARING
1.5

 TYPE OF BEARING______________________________     3
 NUMBER OF ROLLING ELEMENTS___________________          0.00000
 DIAMETER OF ROLLING ELEMENTS_________________          0.00000
 CONTACT ANGLE (BALL BEARING ONLY)____________          0.00000
 RADIAL TO THRUST RATIO
 (TAPER ROLLER BEARING ONLY)__________________          0.00000
 BASIC DYNAMIC CAPACITY_______________________      14000.00000
 ROTATION FACTOR______________________________          1.00000
 WEIBULL EXPONENT_____________________________          1.50000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0
PINION BEARING #2
TYPE OF BEARING - ENTER NUMBER
  1 - SINGLE ROW BALL BEARING
  2 - DOUBLE ROW BALL BEARING
  3 - SINGLE ROW ROLLER BEARING
  4 - DOUBLE ROW ROLLER BEARING
  5 - SINGLE ROW TAPERED ROLLER BEARING
  6 - DOUBLE ROW TAPERED ROLLER BEARING
2
```

```
NUMBER OF BALLS OR ROLLERS
14
DIAMETER OF BALLS  OR ROLLERS
.5625
BEARING CONTACT ANGLE
35
ENTER THE BASIC DYNAMIC CAPACITY OF BEARING
25000
ENTER THE ROTATION FACTOR
1.0 FOR INNER RACE ROTATION
1.2 FOR OUTER RACE ROTATION
1.
WHAT IS THE WEIBULL EXPONENT FOR THE BEARING
1.5

 TYPE OF BEARING______________________________        2
 NUMBER OF ROLLING ELEMENTS___________________           14.00000
 DIAMETER OF ROLLING ELEMENTS_________________            0.56250
 CONTACT ANGLE (BALL BEARING ONLY)____________           35.00000
 RADIAL TO THRUST RATIO
 (TAPER ROLLER BEARING ONLY)__________________            0.00000
 BASIC DYNAMIC CAPACITY_______________________        25000.00000
 ROTATION FACTOR______________________________            1.00000
 WEIBULL EXPONENT_____________________________            1.50000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0
GEAR MOUNTING
WHICH CASE OF BEARING PLACEMENT IS BEING USED
CASE # 1
BEARING-------GEAR----------BEARING
  #1                          #2
*------A--------*------B-------*

CASE # 2
GEAR---------BEARING--------BEARING
               #1             #2
*------A--------*
#---------------B--------------#
2
WHICH BEARING CARRIES THE THRUST LOAD
BEARING #1 OR BEARING #2
2
ENTER DISTANCE A - DISTANCE FROM * TO * (IN)
.9
ENTER DISTANCE B - DISTANCE FROM * TO * (IN)
2.6
```

```
CASE NUMBER                                 2
BEARING TAKING THE THRUST LOAD              2
DISTANCE A                                            -0.9000
DISTANCE B                                             2.6000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0
PINION BEARING #1
TYPE OF BEARING - ENTER NUMBER
  1 - SINGLE ROW BALL BEARING
  2 - DOUBLE ROW BALL BEARING
  3 - SINGLE ROW ROLLER BEARING
  4 - DOUBLE ROW ROLLER BEARING
  5 - SINGLE ROW TAPERED ROLLER BEARING
  6 - DOUBLE ROW TAPERED ROLLER BEARING
3
ENTER THE BASIC DYNAMIC CAPACITY OF BEARING
20000
ENTER THE ROTATION FACTOR
1.0 FOR INNER RACE ROTATION
1.2 FOR OUTER RACE ROTATION
1.0
WHAT IS THE WEIBULL EXPONENTFOR THE BEARING
1.5

 TYPE OF BEARING______________________________     3
 NUMBER OF ROLLING ELEMENTS___________________          0.00000
 DIAMETER OF ROLLING ELEMENTS_________________          0.00000
 CONTACT ANGLE (BALL BEARING ONLY)____________         -0.00000
 RADIAL TO THRUST RATIO
 (TAPER ROLLER BEARING ONLY)__________________          0.00000
 BASIC DYNAMIC CAPACITY_______________________      20000.00000
 ROTATION FACTOR______________________________          1.00000
 WEIBULL EXPONENT_____________________________          1.50000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0
PINION BEARING #2
TYPE OF BEARING - ENTER NUMBER
  1 - SINGLE ROW BALL BEARING
  2 - DOUBLE ROW BALL BEARING
  3 - SINGLE ROW ROLLER BEARING
  4 - DOUBLE ROW ROLLER BEARING
  5 - SINGLE ROW TAPERED ROLLER BEARING
  6 - DOUBLE ROW TAPERED ROLLER BEARING
2
```

```
NUMBER OF BALLS OR ROLLERS
25
DIAMETER OF BALLS  OR ROLLERS
.375
BEARING CONTACT ANGLE
27
ENTER THE BASIC DYNAMIC CAPACITY OF BEARING
19076
ENTER THE ROTAT'ON FACTOR
1.0 FOR INNER RACF ROTATION
1.2 FOR OUTER RACE ROTATION
1.
WHAT IS THE WEIBULL EXPONENT FOR THE BEARING
1.5

 TYPE OF BEARING______________________________      2
 NUMBER OF ROLLING ELEMENTS___________________          25.00000
 DIAMETER OF ROLLING ELEMENTS_________________           0.37500
 CONTACT ANGLE (BALL BEARING ONLY)____________          27.00000
 RADIAL TO THRUST RATIO
 (TAPER ROLLER BEARING ONLY)__________________           0.00000
 BASIC DYNAMIC CAPACITY_______________________       19076.00000
 ROTATION FACTOR______________________________           1.00000
 WEIBULL EXPONENT_____________________________           1.50000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0


 PLANETARY GEAR UNIT INPUTS


DO YOU WISH TO USE A DATA FILE (YES OR NO)
NO
                    PLANETARY TRANSMISSION RELIABILTY ANALYSIS

                    (ALL NUMERICAL INPUT MUST BE IN F-FORMAT)

     WHAT IS THE BASIC DYNAMIC CAPACITY OF ONE PLANET BEARING? (LB)
20895
     WHAT IS THE COMPOSITE LIFE ADJUSTMENT FACTOR?
2.5
     WHAT IS THE OUTER RACE ROTATION FACTOR?
1.0
     WHAT IS THE WEIBULL FACTOR FOR THE BEARINGS?
1.5
     WHAT IS THE LOAD-LIFE FACTOR FOR THE BEARINGS?
3.33
     HOW MANY PLANET BEARINGS ARE IN THE TRANSMISSION?
3
```

```
     IS THE DIAMETRAL PITCH THE SAME FOR BOTH MESHES?
NO
     ENTER THE DIAMETRAL PITCH OF THE SUN MESH FIRST,
     THEN, ENTER THE DIAMETRAL PITCH OF THE RING MESH. (TEETH/IN)
8.8710
9.1429
     HOW MANY TEETH DOES THE SUN GEAR HAVE ON IT?
27
     IS THE PRESSURE ANGLE FOR THE SUN MESH AND
     THE RING MESH THE SAME?
NO
     ENTER THE PRESSURE ANGLE FOR THE SUN MESH FIRST,
     THEN ENTER THE PRESSURE ANGLE OF THE RING MESH. (DEG)
20
14.0682
     WHAT IS THE FACE WIDTH OF THE SUN MESH? (IN)
3.178
     WHAT IS THE WEIBULL EXPONENT OF THE SUN MESH?
2.5
     WHAT IS THE LOAD-LIFE FACTOR OF THE SUN MESH?
4.3
     WHAT IS THE MATERIAL CONSTANT OF THE SUN MESH? (PSI)
20800
     DOES THE TRANSMISSION HAVE STEPPED PLANETS?
YES
     ENTER THE NUMBER OF TEETH ON ONE PLANET MESHED
     WITH THE SUN, THEN ENTER THE NUMBER OF TEETH ON THE
     PLANET MESHED WITH THE RING.
35
35
     HOW MANY TEETH ARE ON THE RING GEAR?
99
     WHAT IS THE FACE WIDTH OF THE RING GEAR MESH? (IN)
2.540
     WHAT IS THE WEIBULL EXPONENT OF THE RING GEAR MESH?
2.5
     WHAT IS THE LOAD-LIFE FACTOR OF THE RING GEAR MESH?
4.3
     WHAT IS THE MATERIAL CONSTANT OF THE RING GEAR MESH? (TEETH/IN)
20800
```

APPENDIX B

PROGRAM OUTPUT

SPIRAL BEVEL GEAR UNIT

GEAR MESH CHARACTERISTICS

PITCH	8.39
NORMAL PRESSURE ANGLE	20.00
SPIRAL ANGLE	25.00
HAND OF THE SPIRAL OF THE PINION GEAR	-1.000
FACE WIDTH	1.800 IN
CONE DISTANCE	5.200 IN
INPUT SPEED OF THE PINION SHAFT	6180.00 RPM
OUTPUT SPEED OF GEAR SHAFT	1653.80 RPM
DIRECTION OF INPUT SHAFT ROTATION	-1.000
INPUT TORQUE OF THE PINION SHAFT	3262.00 IN-LB
OUTPUT TORQUE OF THE GEAR SHAFT	12189.58 IN-LB
ANGLE BETWEEN INPUT AND OUTPUT SHAFT	95.00 DEG

PINION CHARACTERISTICS AND MOUNTING

NUMBER OF TEETH	19.00
PITCH ANGLE	15.27 DEG
PITCH DIAMETER	2.26 IN
REFERENCE PITCH DIAMETER	1.174 IN
ADDENDUM	0.144 IN
DEDENDUM	0.230 IN

FORCES ON A TOOTH IN THE MESH

AXIAL FORCE	991.4 LB
RADIAL FORCE	-1469.9 LB
TANGENTIAL FORCE	-2881.0 LB
TOTAL FORCE	3382.8 LB
DYNAMIC CAPACITY IN FORCE	4712.7 LB

MOUNTING CHARACTERISTICS

TYPE OF MOUNTING	1
DISTANCE A	1.300
DISTANCE B	2.500
AXIAL LOAD	0.00 LBS
RADIAL LOAD	1262.43 LBS
TANGENTIAL LOAD	1895.38 LBS
TOTAL EQUIVALENT FORCE	2277.33 LBS
BASIC DYNAMIC CAPACITY OF BEARING #1	7771.4 LBS
AXIAL LOAD	991.35 LBS
RADIAL LOAD	207.48 LBS
TANGENTIAL LOAD	985.60 LBS
TOTAL EQUIVALENT FORCE	1665.07 LBS
BASIC DYNAMIC CAPACITY OF BEARING #2	13084.3 LBS

DYNAMIC CAPACITY IN FORCE

GEAR CHARACTERISTICS AND MOUNTING

NUMBER OF TEETH	71.00
PITCH ANGLE	79.73 DEG
PITCH DIAMETER	8.46 IN
REFERENCE PITCH DIAMETER	23.738 IN
ADDENDUM	0.058 IN
DEDENDUM	0.172 IN

FORCES ON A TOOTH IN THE MESH

AXIAL FORCE	-1377.9 LB
RADIAL FORCE	1115.7 LB
TANGENTIAL FORCE	-2881.0 LB
TOTAL FORCE	3382.8 LB
DYNAMIC CAPACITY IN FORCE	5664.4 LB

MOUNTING CHARACTERISTICS

TYPE OF MOUNTING	2
DISTANCE A	-0.900
DISTANCE B	2.600
AXIAL LOAD	0.00 LBS
RADIAL LOAD	-5135.78 LBS
TANGENTIAL LOAD	4406.21 LBS
TOTAL EQUIVALENT FORCE	6766.90 LBS
BASIC DYNAMIC CAPACITY OF BEARING #1	16553.4 LBS

AXIAL LOAD	-1377.92 LBS
RADIAL LOAD	4020.09 LBS
TANGENTIAL LOAD	-1525.23 LBS
TOTAL EQUIVALENT FORCE	5374.48 LBS
BASIC DYNAMIC CAPACITY OF BEARING #2	15492.9 LBS

DYNAMIC CAPACITY IN FORCE

DYNAMIC CAPACITY AND LIFE IN TERMS OF
OUTPUT TORQUE AND SPEED

INPUT PINION

DYNAMIC CAPACITY	79248.2031 LB-IN
LOAD LIFE EXPONENT	4.3000
LIFE IN MILLION OUTPUT ROTATIONS	4.1608
LIFE IN HOURS	195.6793
WEIBULL EXPONENT	2.5000

INPUT BEARING #1

DYNAMIC CAPACITY	194120.0313 LB-IN
LOAD LIFE EXPONENT	3.3000
LIFE IN MILLION OUTPUT ROTATIONS	57.4310
LIFE IN HOURS	2700.9629
WEIBULL EXPONENT	1.5000

INPUT BEARING #2

DYNAMIC CAPACITY	447005.4375 LB-IN
LOAD LIFE EXPONENT	3.0000
LIFE IN MILLION OUTPUT ROTATIONS	485.2344
LIFE IN HOURS	22820.4141
WEIBULL EXPONENT	1.5000

OUTPUT GEAR

DYNAMIC CAPACITY	95251.9375 LB-IN
LOAD LIFE EXPONENT	4.3000
LIFE IN MILLION OUTPUT ROTATIONS	9.1765
LIFE IN HOURS	431.5667
WEIBULL EXPONENT	2.5000

OUTPUT BEARING #1

DYNAMIC CAPACITY	139153.4688 LB-IN
LOAD LIFE EXPONENT	3.3000
LIFE IN MILLION OUTPUT ROTATIONS	19.1445
LIFE IN HOURS	900.3616
WEIBULL EXPONENT	1.5000

OUTPUT BEARING #2

DYNAMIC CAPACITY	163979.9688 LB-IN
LOAD LIFE EXPONENT	3.0000
LIFE IN MILLION OUTPUT ROTATIONS	23.9544
LIFE IN HOURS	1126.5688
WEIBULL EXPONENT	1.5000

INPUT TORQUE............................	12189.58008 LB-IN
OUTPUT TORQUE...........................	56884.71094 LB-IN
INPUT SPEED.............................	1653.80273 RPM
OUTUT SPEED.............................	354.38629 RPM

PLANET BEARING

NUMBER OF PLANETS.......................	3.00000
ROTATIONAL FACTOR.......................	1.00000
DYNAMIC CAPACITY (CATALOG VALUE).......	20895.00000 LBS
DYNAMIC CAPACITY (SYSTEM VALUE)........	20107.14844 LBS
TOTAL FORCE............................	5421.77441 LBS

SUN GEAR

NUMBER OF TEETH.........................	27.00000
PITCH OF THE MESH.......................	8.87100
PRESSURE ANGLE..........................	20.00000 DEG
FACE WIDTH..............................	3.17800 IN
MATERIAL CONSTANT OF THE MESH...........	20800.00000 PSI
DYNAMIC CAPACITY	8184.11816 LBS
FORCE ON GEAR TOOTH.....................	2669.96924 LBS

RING GEAR

NUMBER OF TEETH.........................	99.00000
PITCH OF THE MESH.......................	9.14290
PRESSURE ANGLE..........................	14.06820 DEG
FACE WIDTH..............................	2.54000 IN
MATERIAL CONSTANT OF THE MESH...........	20800.00000 PSI
DYNAMIC CAPACITY	19206.60547 LBS
FORCE ON GEAR TOOTH.....................	2751.80518 LBS

PLANET GEAR

PLANET-SUN GEAR

NUMBER OF TEETH........................	35.00000
PITCH OF THE MESH......................	8.87100
PRESSURE ANGLE.........................	20.00000 DEG
FACE WIDTH.............................	3.17800 IN
MATERIAL CONSTANT OF THE MESH..........	20800.00000 PSI
DYNAMIC CAPACITY	10956.11523 LBS
FORCE ON GEAR TOOTH....................	2669.96924 LBS

PLANET-RING GEAR

NUMBER OF TEETH........................	35.00000
PITCH OF THE MESH......................	9.14290
PRESSURE ANGLE.........................	14.06820 DEG
FACE WIDTH.............................	2.54000 IN
MATERIAL CONSTANT OF THE MESH..........	20800.00000 PSI
DYNAMIC CAPACITY	21448.64063 LBS
FORCE ON GEAR TOOTH....................	2751.80518 LBS

DYNAMIC CAPACITY AND LIFE IN TERMS OF
OUTPUT TORQUE AND SPEED

PLANET BEARING

DYNAMIC CAPACITY	210962.1875 LB-IN
LOAD LIFE EXPONENT	3.3300
LIFE IN MILLION OUTPUT ROTATIONS	78.6079
LIFE IN HOURS	3696.9014
WEIBULL EXPONENT	1.5000

SUN GEAR

DYNAMIC CAPACITY	174365.7500 LB-IN
LOAD LIFE EXPONENT	4.3000
LIFE IN MILLION OUTPUT ROTATIONS	123.5385
LIFE IN HOURS	5809.9727
WEIBULL EXPONENT	2.5000

AD-A172 564 SYSTEM LIFE AND RELIABILITY MODELING FOR HELICOPTER TRANSMISSIONS(U) AKRON UNIV OH DEPT OF MECHANICAL ENGINEERING M SAVAGE ET AL APR 86 NASA-CR-3967 2/3

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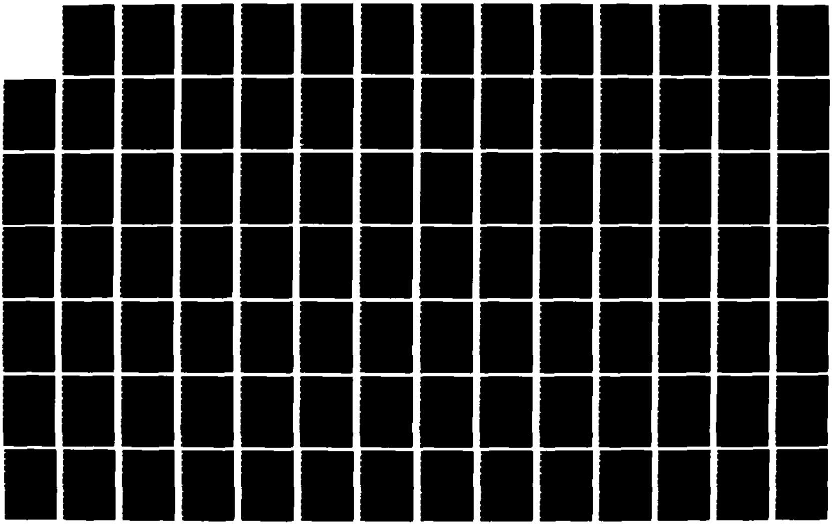

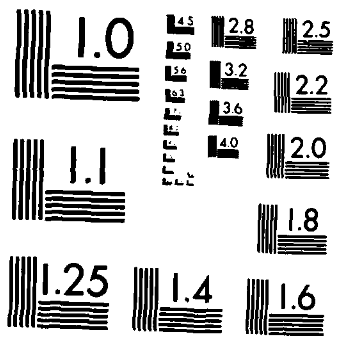

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

RING GEAR

DYNAMIC CAPACITY	397034.7500	LB-IN
LOAD LIFE EXPONENT	4.3000	
LIFE IN MILLION OUTPUT ROTATIONS	4250.9033	
LIFE IN HOURS	199918.5625	
WEIBULL EXPONENT	2.5000	

PLANET-SUN GEAR

DYNAMIC CAPACITY	233424.2188	LB-IN
LOAD LIFE EXPONENT	4.3000	
LIFE IN MILLION OUTPUT ROTATIONS	433.0579	
LIFE IN HOURS	20366.5664	
WEIBULL EXPONENT	2.5000	

PLANET-RING GEAR

DYNAMIC CAPACITY	443381.5625	LB-IN
LOAD LIFE EXPONENT	4.3000	
LIFE IN MILLION OUTPUT ROTATIONS	6833.7959	
LIFE IN HOURS	321391.1250	
WEIBULL EXPONENT	2.5000	

SPIRAL BEVEL UNIT

DYNAMIC CAPACITY	77358.9844	LB-IN
LOAD LIFE EXPONENT	4.0239	
LIFE IN MILLION OUTPUT ROTATIONS	3.6746	
LIFE IN HOURS	172.8132	
WEIBULL EXPONENT	2.3646	

PLANETARY UNIT

DYNAMIC CAPACITY	153544.4688	LB-IN
LOAD LIFE EXPONENT	3.5845	
LIFE IN MILLION OUTPUT ROTATIONS	36.4289	
LIFE IN HOURS	1713.2412	
WEIBULL EXPONENT	1.5850	

TOTAL TRANSMISSION

DYNAMIC CAPACITY	77164.9063	LB-IN
LOAD LIFE EXPONENT	4.0005	
LIFE IN MILLION OUTPUT ROTATIONS	3.6267	
LIFE IN HOURS	170.5630	
WEIBULL EXPONENT	2.3433	

APPENDIX C

PROGRAM LISTING

```
      WRITE(1,10)
10    FORMAT(//
     1' HELICOPTER TRANSMISSION ANALYSIS'/
     2' ENTER THE NUMBER FOR THE TYPE OF TRANSMISSION'/
     3' SPIRAL BEVEL.................................1'/
     4' PLANETARY....................................2'/
     5' SPIRAL BEVEL + PLANETARY.....................3'/
     6' SPIRAL BEVEL + PLANETARY + PLANETARY.........4'/
     7' DUAL SPIRAL BEVEL............................5'/
     8' DUAL SPIRAL BEVEL + PLANETARY................6'/
     9' DUAL SPIRAL BEVEL + PLANETARY + PLANETARY......7'/
     1' SPIRAL BEVEL + DUAL SPIRAL BEVEL + PLANETARY...8'/)
      READ(1,*)NT
      IF(NT.EQ.1)CALL SPBV
      IF(NT.EQ.2)CALL PLAN
      IF(NT.EQ.3)CALL SBPL
      IF(NT.EQ.4)CALL SBPLPL
      IF(NT.EQ.5)CALL DPBV
      IF(NT.EQ.6)CALL DBPL
      IF(NT.EQ.7)CALL DBPLPL
      IF(NT.EQ.8)CALL SBDBPL
      STOP
      END
      SUBROUTINE SPBV
      INTEGER CASEP,CASEG,PTL,GTL
      REAL NP,NG,NBP1,NBP2,NBG1,NBG2,MG,MG1,LSB
      REAL L1(6),D1(6),E1(6),H1(6),P1(6),DYN(10),LI(10)
101   FORMAT('WHAT IS THE INPUT TORQUE OF THE TRANSMISSION')
102   FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
      WRITE(1,101)
      READ(1,*)TI
      WRITE(1,102)
      READ(1,*)SI
C
C     INPUT SPIRAL BEVEL GEAR GEOMETRY
C
      CALL SPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,E1(1),PG,
     1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
     2BDCAP1,RFP1,E1(2),ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,E1(3),
     3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,E1(5),
     4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,E1(6),MG,GAMMA1,GAMMA,ZZ,
     5ZZ1,DP,DG,RPD,RP,RGD,RG,HK,AOG,AOP,HT,BOG,BOP,PITCH,
     6ADJP1,ADJP2,ADJG1,ADJG2)
```

```
C
      E1(4)=E1(1)
      P1(1)=PG
      P1(4)=PG
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION
C
      TOF=TI*MG
      SOF=SI/MG
      MG1=1.0
C
C     CALCULATE LIVES AND DYNAMIC CAPACITIES OF SPIRAL BEVEL
C     COMPONENTS AND LIFE OF THE TRANSMISSION
C
      CALL SPBVCA(
     1TI,TOF,SI,SOF,MG,MG1,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
     8F,E,PG,E1(1),RPD,RGD,
     9PXP,PYP,PZP,TOTFOR,PXG,PYG,PZG,TOTFOR,
     1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1,P1(2),BDCAP1O,D1(2),
     4L1(3),H1(3),TOFORP2,P1(3),BDCAP2O,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
     7L1(1),H1(1),DCAP,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     9LSB,HSB,ESB)
C
C     PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS
C
      CALL SPBVOT(PD,PHE,PHSI,SPR,F,AO,SI,SOF,ROT,TI,TOF,THETA,
     1NP,GAMMA,DP,RPD,AOP,BOP,PITCH,
     2PXP,PYP,PZP,TOTFOR,DCAP,CASEP,AP,BP,
     3R1XP,R1YP,R1ZP,TOFORP1,BDCAP1O,
     4R2XP,R2YP,R2ZP,TOFORP2,BDCAP2O,
     5NG,ZZ,DG,RGD,AOG,BOG,
     6PXG,PYG,PZG,TOTFOR,DCAG,CASEG,AG,BG,
     7R1XG,R1YG,R1ZG,TOFORG1,BDCAG1O,
     8R2XG,R2YG,R2ZG,TOFORG2,BDCAG2O,
```

```
     9D1,P1,L1,H1,E1)
C
C     ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION
C
      DMIN=D1(1)
      DO 10 I=2,6
10        IF(D1(I).LT.DMIN)DMIN=D1(I)
          DELTATO=.1*DMIN
          DELTATI=DELTATO/MG
          DTI=0.0
          DTO=0.0
C
C      START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT
C      OF TRANSMISSION DYNAMIC CAPACITY
C
          DO 20 I=1,10
              DTI=DTI+DELTATI
              DTO=DTO+DELTATO
              DYN(I)=DTO
C
C     CALCULATE LIFE FOR EACH DYNAMIC CAPACITY
C
      CALL SPBVCA(
     1DTI,DTO,SI,SOF,MG,MG1,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
     8F,E,PG,E1(1),RPD,RGD,
     9PXP,PYP,PZP,TOTFOR,PXG,PYG,PZG,TOTFOR,
     1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1,P1(2),BDCAP10,D1(2),
     4L1(3),H1(3),TOFORP2,P1(3),BDCAP20,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG10,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG20,D1(6),
     7L1(1),H1(1),DCAP,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     9LI(I),HSB1,ESB1)
20    CONTINUE
C
C     CALCULATE DYNAMIC CAPACITY AND LOAD LIFE EXPONENT FOR TRANSMISSION
C
```

```
      CALL CAP(DYN,LI,10,DSB,PSP)
C
C     PRINT OUT LIFE AND DYNAMIC CAPACITY OF TRANSMISSION
C
      WRITE(1,1220)
1220  FORMAT('    TOTAL TRANSMISSION'/)
      CALL DPLHE(DSB,PSP,LSB,HSB,ESB)
      STOP
      END
      SUBROUTINE SBPL
      INTEGER CASEP,CASEG,PTL,GTL
      REAL NP,NG,NBP1,NBP2,NBG1,NBG2,MG,LSB
      REAL L1(6),D1(6),E1(6),H1(6),P1(6),DYN(10),LI(10)
      REAL NS,NPS,NPR,NR,N,LS,LR,LPLAN
      REAL NCOMP(5),AD1(5),AP1(5),AL1(5),AH1(5),AE1(5),ALI(10)
      REAL MGS,MGP,ZNCOMP(11),ZE1(11),ZL1(11),LTRANS,ZLI(10)
101   FORMAT('WHAT IS THE INPUT TORQUE OF THE TRANSMISSION')
102   FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
      WRITE(1,101)
      READ(1,*)TI
      WRITE(1,102)
      READ(1,*)SI
C
C     READ IN VALUES OF THE SPIRAL BEVEL UNIT
C
      CALL SPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,E1(1),PG,
     1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
     2BDCAP1,RFP1,E1(2),ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,E1(3),
     3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,E1(5),
     4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,E1(6),MG,GAMMA1,GAMMA,ZZ,
     5ZZ1,DP,DG,RPD,RP,RGD,RG,HK,AOG,AOP,HT,BOG,BOP,PITCH,
     6ADJP1,ADJP2,ADJG1,ADJG2)
C
      E1(4)=E1(1)
      P1(1)=PG
      P1(4)=PG
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF SPIRAL BEVEL UNIT
C
      TOS=TI*MG
      SOS=SI/MG
C
C     READ IN VALUES OF PLANETARY UNIT
C
      CALL PLANIN(CB,A,V,EB,PB,N,NCOMP,PDS,PDR,NS,PHIS,PHIS1,
```

```
     1PHIR,PHIR1,WDSM,ES,PS,B1SM,ISTEP,NPS,NPR,NR,WDRM,ER,PR,B1RM,
     2RPR,RPS,RR,RS)
      AP1(1)=PB
      AP1(2)=PS
      AP1(3)=PR
      AP1(4)=PS
      AP1(5)=PR
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT
C
      TOF=TOS*(1.+(RR*RPS)/(RS*RPR))
      SOF=SOS/(1.+(RR*RPS)/(RS*RPR))
      MQS=(1.+(RR*RPS)/(RS*RPR))
      MQP=1.0
      INCOMP=6+ISTEP
      DO 5 IN=1,6
5     ZNCOMP(IN)=1.0
      DO 6 IN=1,ISTEP
6     ZNCOMP(IN+6)=NCOMP(IN)
C
C     CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C     CALCULATE LIFE OF SPIRAL BEVEL UNIT
C
      CALL SPBVCA(
     1TI,TOF,SI,SOF,MQ,MQS,NP,NQ,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,
     3PTL,AP,BP,RP,QTL,AQ,BQ,RQ,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEQ1,RFQ1,NBQ1,DQ1,ACQ1,BDCAQ1,AK3,E1(5),ADJQ1,
     7ITYPEQ2,RFQ2,NBQ2,DQ2,ACQ2,BDCAQ2,AK4,E1(6),ADJQ2,
     8F,E,PQ,E1(1),RPD,RQD,
     9PXP,PYP,PZP,TOTFOR,PXQ,PYQ,PZQ,TOTFOR,
     1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
     2R1XQ,R1YQ,R1ZQ,R2XQ,R2YQ,R2ZQ,
     3L1(2),H1(2),TOFORP1,P1(2),BDCAP1O,D1(2),
     4L1(3),H1(3),TOFORP2,P1(3),BDCAP2O,D1(3),
     5L1(5),H1(5),TOFORQ1,P1(5),BDCAQ1O,D1(5),
     6L1(6),H1(6),TOFORQ2,P1(6),BDCAQ2O,D1(6),
     7L1(1),H1(1),DCAP,D1(1),
     8L1(4),H1(4),DCAQ,D1(4),
     9LSB,HSB,ESB)
C
C     PRINT OUT RESULTS FOR SPIRAL BEVEL UNIT
C
```

```
      CALL SPBVOT(PD,PHE,PHSI,SPR,F,AO,SI,SOS,ROT,TI,TOS,THETA,
     1NP,GAMMA,DP,RPD,AOP,BOP,PITCH,
     2PXP,PYP,PZP,TOTFOR,DCAP,CASEP,AP,BP,
     3R1XP,R1YP,R1ZP,TOFORP1,BDCAP1O,
     4R2XP,R2YP,R2ZP,TOFORP2,BDCAP2O,
     5NQ,ZZ,DQ,RQD,AOQ,BOQ,
     6PXQ,PYQ,PZQ,TOTFOR,DCAQ,CASEQ,AQ,BQ,
     7R1XQ,R1YQ,R1ZQ,TOFORQ1,BDCAQ1O,
     8R2XQ,R2YQ,R2ZQ,TOFORQ2,BDCAQ2O,
     9D1,P1,L1,H1,E1)
C
C     CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C     CALCULATE LIFE OF PLANETARY UNIT
C
      CALL PLANCA(ISTEP,NCOMP,MGP,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3TOS,TOF,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,
     4LPLAN,HPLAN,EPLAN)
C
C     PRINT OUT RESULTS FOR THE PLANETARY UNIT
C
      CALL PLANOT(ISTEP,N,V,CB,FB,NS,PDS,PHIS,WDSM,B1SM,FS,
     1NR,PDR,PHIR,WDRM,B1RM,FR,NP,NPS,NPR,TOS,TOF,SOS,SOF,FTT,
     2AD1,AP1,AL1,AH1,AE1)
C
C     DEFINE TRANSMISSION LIFE ARRAYS
C
      DO 8 IE=1,6
          ZE1(IE)=E1(IE)
8         ZL1(IE)=L1(IE)
          DO 9 IE=1,ISTEP
              ZE1(IE+6)=AE1(IE)
9             ZL1(IE+6)=AL1(IE)
       CALL LIFE(ZL1,INCOMP,ZE1,ZNCOMP,LTRANS,ETRANS)
       HTRANS=LTRANS*16666.667/SOF
C
C      START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C      CAPACITY
       DMIN=D1(1)
       DO 21 I=2,6
21     IF(D1(I).LT.DMIN)DMIN=D1(I)
       DELTATO=.15*DMIN
       DELTATI=DELTATO/MGS/MG
       DTO=0.0
```

```
      DTI=0.0
      DO 22 I=1,10
         DTI=DTI+DELTATI
         DTO=DTO+DELTATO
         DYN(I)=DTO
     CALL SPBVCA(
    1DTI,DTO,SI,SOF,MG,MGS,NP,NG,
    2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,
    3PTL,AP,BP,RP,QTL,AG,BG,RG,
    4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
    5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
    6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
    7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
    8F,E,PG,E1(1),RPD,RGD,
    9PXP,PYP,PZP,TOTFOR,PXG,PYG,PZG,TOTFOR,
    1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
    2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
    3L1(2),H1(2),TOFORP1,P1(2),BDCAP1O,D1(2),
    4L1(3),H1(3),TOFORP2,P1(3),BDCAP2O,D1(3),
    5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
    6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
    7L1(1),H1(1),DCAP,D1(1),
    8L1(4),H1(4),DCAG,D1(4),
    9LI(I),DUMB,DUMB)
22   CONTINUE
     CALL CAP(DYN,LI,10,DSB,PSP)
C
C
C
C     START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C     CAPACITY
C
     ADMIN=AD1(1)
     DO 23 I=2,ISTEP
23       IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
            DELTATO=.15*ADMIN
            DELTATOS=DELTATO/MGS
            DTO=0.0
            DTOS=0.0
               DO 24 I=1,10
                  DTOS=DTOS+DELTATOS
                  DTO=DTO+DELTATO
                  DYN(I)=DTO
     CALL PLANCA(ISTEP,NCOMP,MGP,NS,NPS,NPR,NR,PHIS1,PHIR1,
    1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
```

```
     2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
     3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB,
     4DUMB)
24    CONTINUE
      CALL CAP(DYN, ALI, 10, DPLAN, PPLAN)
C
C       START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C       CAPACITY
C
      IF(ADMIN.LT.DMIN)DMIN=ADMIN
           DELTATO=.15*DMIN
           DELTATOS=DELTATO/MGS
           DELTATI=DELTATOS/MG
           DTI=0.0
           DTOS=0.0
           DTO=0.0
           DO 20 I=1,10
                DTI=DTI+DELTATI
                DTOS=DTOS+DELTATOS
                DTO=DTO+DELTATO
                DYN(I)=DTO
C
C
C
      CALL SPBVCA(
     1DTI, DTO, SI, SOF, MG, MGS, NP, NG,
     2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1,
     3PTL, AP, BP, RP, GTL, AG, BG, RG,
     4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
     5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
     6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
     7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
     8F, E, PG, E1(1), RPD, RGD,
     9PXP, PYP, PZP, TOTFOR, PXG, PYG, PZG, TOTFOR,
     1R1XP, R1YP, R1ZP, R2XP, R2YP, R2ZP,
     2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
     3L1(2), H1(2), TOFORP1, P1(2), BDCAP10, D1(2),
     4L1(3), H1(3), TOFORP2, P1(3), BDCAP20, D1(3),
     5L1(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5),
     6L1(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6),
     7L1(1), H1(1), DCAP, D1(1),
     8L1(4), H1(4), DCAG, D1(4),
     9LI(I), DUMB, DUMB)
      CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1,
     1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
```

```
     2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
     3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB,
     4DUMB)
      DO 12 IE=1,6
12        ZL1(IE)=L1(IE)
          DO 13 IE=1, ISTEP
13            ZL1(IE+6)=AL1(IE)
       CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, ZLI(I), DUMB)
20    CONTINUE
      CALL CAP(DYN, ZLI, 10, DTRANS, PTRANS)
1220  FORMAT('     TOTAL TRANSMISSION'/)
1221  FORMAT('     SPIRAL BEVEL UNIT'/)
1222  FORMAT('     PLANETARY UNIT'/)
      WRITE(1, 1221)
      CALL DPLHE(DSB, PSP, LSB, HSB, ESB)
      WRITE(1, 1222)
      CALL DPLHE(DPLAN, PPLAN, LPLAN, HPLAN, EPLAN)
      WRITE(1, 1220)
      CALL DPLHE(DTRANS, PTRANS, LTRANS, HTRANS, ETRANS)
      STOP
      END

      SUBROUTINE SBPLPL
      INTEGER CASEP, CASEG, PTL, GTL, BISTEP
      REAL NP, NG, NBP1, NBP2, NBG1, NBG2, MG, LSB
      REAL L1(6), D1(6), E1(6), H1(6), P1(6), DYN(10), LI(10)
      REAL NS, NPS, NPR, NR, N, LS, LR, LPLAN
      REAL NCOMP(5), AD1(5), AP1(5), AL1(5), AH1(5), AE1(5), ALI(10)
      REAL MGS, MGPA, MGPB, ZNCOMP(16), ZE1(16), ZL1(16), LTRANS, ZLI(10)
      REAL BNCOMP(5), BD1(5), BP1(5), BL1(5), BH1(5), BE1(5), BLI(10)
101   FORMAT('WHAT IS THE INPUT TORQUE OF THE TRANSMISSION')
102   FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
      WRITE(1, 101)
      READ(1, *)TI
      WRITE(1, 102)
      READ(1, *)SI
C
C     READ IN VALUES OF THE SPIRAL BEVEL UNIT
C
      CALL SPBVIN(NP, NG, AO, PHE, F, PHSI, ROT, SPR, THETA, E, E1(1), PG,
     1PHE1, PHSI1, THETA1, CASEP, PTL, AP, BP, ITYPEP1, NBP1, DP1, ACP1, AK1,
     2BDCAP1, RFP1, E1(2), ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAP2, RFP2, E1(3),
     3CASEG, GTL, AG, BG, ITYPEG1, NBG1, DG1, ACG1, AK3, BDCAG1, RFG1, E1(5),
     4ITYPEG2, NBG2, DG2, ACG2, AK4, BDCAG2, RFG2, E1(6), MG, GAMMA1, GAMMA, ZZ,
     5ZZ1, DP, DG, RPD, RP, RGD, RG, HK, AOG, AOP, HT, BOG, BOP, PITCH,
```

```
     6ADJP1, ADJP2, ADJQ1, ADJQ2)
C
C
      E1(4)=E1(1)
      P1(1)=PG
      P1(4)=PG
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF SPIRAL BEVEL UNIT
C
      TOS=TI*MG
      SOS=SI/MG
C
C     READ IN VALUES OF PLANETARY UNIT
C
      CALL PLANIN(CB, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1,
     1PHIR, PHIR1, WDSM, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM,
     2RPR, RPS, RR, RS)
      AP1(1)=PB
      AP1(2)=PS
      AP1(3)=PR
      AP1(4)=PS
      AP1(5)=PR
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT
C
      TOPA=TOS*(1.+(RR*RPS)/(RS*RPR))
      SOPA=SOS/(1.+(RR*RPS)/(RS*RPR))
C
C     READ IN VALUES OF PLANETARY UNIT
C
      CALL PLANIN(BCB, BA, BV, BEB, BPB, BN, BNCOMP, BPDS, BPDR, BNS, BPHIS,
     1BPHIS1, BPHIR, BPHIR1, BWDSM, BES, BPS, BB1SM, BISTEP, BNPS,
     2BNPR, BNR, BWDRM, BER, BPR, BB1RM, BRPR, BRPS, BRR, BRS)
      BP1(1)=BPB
      BP1(2)=BPS
      BP1(3)=BPR
      BP1(4)=BPS
      BP1(5)=BPR
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT
C
      TOF=TOPA*(1.+(BRR*BRPS)/(BRS*BRPR))
      SOF=SOPA/(1.+(BRR*BRPS)/(BRS*BRPR))
      MGPA=(1.+(BRR*BRPS)/(BRS*BRPR))
      MGS=(1.+(RR*RPS)/(RS*RPR))*MGPA
```

```
      MGPB=1.0
      INCOMP=6+ISTEP+BISTEP
      DO 5 IN=1,6
5     ZNCOMP(IN)=1.0
      DO 6 IN=1,ISTEP
6     ZNCOMP(IN+6)=NCOMP(IN)
      IX=6+ISTEP
      DO 77 IN=1,BISTEP
77    ZNCOMP(IN+IX)=BNCOMP(IN)
C
C     CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C     CALCULATE LIFE OF SPIRAL BEVEL UNIT
C
      CALL SPBVCA(
     1TI,TOF,SI,SOF,MG,MGS,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
     8F,E,PG,E1(1),RPD,RGD,
     9PXP,PYP,PZP,TOTFOR,PXG,PYG,PZG,TOTFOR,
     1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1,P1(2),BDCAP1O,D1(2),
     4L1(3),H1(3),TOFORP2,P1(3),BDCAP2O,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
     7L1(1),H1(1),DCAP,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     9LSB,HSB,ESB)
C
C     PRINT OUT RESULTS FOR SPIRAL BEVEL UNIT
C
      CALL SPBVOT(PD,PHE,PHSI,SPR,F,AO,SI,SOS,ROT,TI,TOS,THETA,
     1NP,GAMMA,DP,RPD,AOP,BOP,PITCH,
     2PXP,PYP,PZP,TOTFOR,DCAP,CASEP,AP,BP,
     3R1XP,R1YP,R1ZP,TOFORP1,BDCAP1O,
     4R2XP,R2YP,R2ZP,TOFORP2,BDCAP2O,
     5NG,ZZ,DG,RGD,AOG,BOG,
     6PXG,PYG,PZG,TOTFOR,DCAG,CASEG,AG,BG,
     7R1XG,R1YG,R1ZG,TOFORG1,BDCAG1O,
     8R2XG,R2YG,R2ZG,TOFORG2,BDCAG2O,
     9D1,P1,L1,H1,E1)
```

```
C
C      CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C      CALCULATE LIFE OF PLANETARY UNIT
C
       CALL PLANCA(ISTEP, NCOMP, MGPA, NS, NPS, NPR, NR, PHIS1, PHIR1,
      1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
      2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
      3TOS, TOF, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1,
      4LPLAN, HPLAN, EPLAN)
C
C      PRINT OUT RESULTS FOR THE PLANETARY UNIT
C
       CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS,
      1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TOS, TOF, SOS, SOF, FTT,
      2AD1, AP1, AL1, AH1, AE1)
C
C      CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C      CALCULATE LIFE OF PLANETARY UNIT
C
       CALL PLANCA(BISTEP, BNCOMP, MGPB, BNS, BNPS, BNPR, BNR,
      1BPHIS1, BPHIR1, BRS, BRPS, BRPR, BRR, BCB, BA, BV, BPB, BN, BEB,
      2BFTT, BB1SM, BPS, BES, BWDSM, BB1RM, BPR, BER, BWDRM,
      3TOPA, TOF, SOPA, SOF, BCS, BLS, BFS, BCR, BLR, BFR, BD1, BL1, BH1, BE1,
      4BLPLAN, BHPLAN, BEPLAN)
C
C      PRINT OUT RESULTS FOR THE PLANETARY UNIT
C
       CALL PLANOT(BISTEP, BN, BV, BCB, BFB, BNS, BPDS, BPHIS, BWDSM,
      1BB1SM, BFS, BNR, BPDR, BPHIR, BWDRM, BB1RM, BFR, BNP, BNPS, BNPR,
      2TOPA, TOF, SOPA, SOF, BFTT, BD1, BP1, BL1, BH1, BE1)
C
C      DEFINE TRANSMISSION LIFE ARRAYS
C
       DO 8 IE=1,6
            ZE1(IE)=E1(IE)
8           ZL1(IE)=L1(IE)
            DO 9 IE=1, ISTEP
                 ZE1(IE+6)=AE1(IE)
9                ZL1(IE+6)=AL1(IE)
                 DO 99 IE=1, BISTEP
                      ZE1(IE+6+ISTEP)=BE1(IE)
99                    ZL1(IE+6+ISTEP)=BL1(IE)
        CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, LTRANS, ETRANS)
        HTRANS=LTRANS*16666.667/SOF
C
```

```
C       START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C       CAPACITY
        DMIN=D1(1)
        DO 21 I=2,6
21      IF(D1(I).LT.DMIN)DMIN=D1(I)
        DELTATO=.15*DMIN
        DELTATI=DELTATO/MGS/MG
        DTO=0.0
        DTI=0.0
        DO 22 I=1,10
            DTI=DTI+DELTATI
            DTO=DTO+DELTATO
            DYN(I)=DTO
       CALL SPBVCA(
     1DTI,DTO,SI,SOF,MG,MGS,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG1,
     8F,E,PG,E1(1),RPD,RGD,
     9PXP,PYP,PZP,TOTFOR,PXG,PYG,PZG,TOTFOR,
     1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1,P1(2),BDCAP10,D1(2),
     4L1(3),H1(3),TOFORP2,P1(3),BDCAP20,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG10,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG20,D1(6),
     7L1(1),H1(1),DCAP,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     9LI(I),DUMB,DUMB)
22      CONTINUE
        CALL CAP(DYN,LI,10,DSB,PSP)
C
C
C
C       START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C       CAPACITY
C
        ADMIN=AD1(1)
        DO 23 I=2,ISTEP
23          IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
                DELTATO=.15*ADMIN
                DELTATOS=DELTATO/MGS
```

```
            DTO=0.0
            DTOS=0.0
                DO 24 I=1,10
                    DTOS=DTOS+DELTATOS
                    DTO=DTO+DELTATO
                    DYN(I)=DTO
      CALL PLANCA(ISTEP,NCOMP,MGPA,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3DTOS,DTO,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,ALI(I),DUMB,
     4DUMB)
24    CONTINUE
      CALL CAP(DYN,ALI,10,DPLAN,PPLAN)
C
C
C
C      START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C      CAPACITY
C
      BDMIN=BD1(1)
      DO 30 I=2,BISTEP
30        IF(BD1(I).LT.BDMIN)BDMIN=BD1(I)
            DELTATO=.15*BDMIN
            DELTATOS=DELTATO/MGPA
            DTO=0.0
            DTOS=0.0
                DO 31 I=1,10
                    DTOS=DTOS+DELTATOS
                    DTO=DTO+DELTATO
                    DYN(I)=DTO
      CALL PLANCA(BISTEP,BNCOMP,MGPB,BNS,BNPS,BNPR,BNR,BPHIS1,
     1BPHIR1,BRS,BRPS,BRPR,BRR,BCB,BA,BV,BPB,BN,BEB,BFTT,
     2BB1SM,BPS,BES,BWDSM,BB1RM,BPR,BER,BWDRM,
     3DTOS,DTO,SOPA,SOF,BCS,BLS,BFS,BCR,BLR,BFR,
     4BD1,BL1,BH1,BE1,BLI(I),DUMB,DUMB)
31    CONTINUE
      CALL CAP(DYN,BLI,10,BDPLAN,BPPLAN)
C
C      START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C      CAPACITY
C
      IF(ADMIN.LT.DMIN)DMIN=ADMIN
      IF(BDMIN.LT.DMIN)DMIN=BDMIN
          DELTATO=.15*DMIN
          DELTATOP=DELTATO/MGPA
```

```
      DELTATOS=DELTATO/MQS
      DELTATI=DELTATOS/MQ
      DTI=0.0
      DTOS=0.0
      DTOPA=0.0
      DTO=0.0
      DO 20 I=1,10
          DTI=DTI+DELTATI
          DTOS=DTOS+DELTATOS
          DTOPA=DTOPA+DELTATOP
          DTO=DTO+DELTATO
          DYN(I)=DTO
C
C
C
       CALL SPBVCA(
     1DTI,DTO,SI,SOF,MQ,MQS,NP,NQ,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,
     3PTL,AP,BP,RP,QTL,AQ,BQ,RQ,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEQ1,RFQ1,NBQ1,DQ1,ACQ1,BDCAQ1,AK3,E1(5),ADJQ1,
     7ITYPEQ2,RFQ2,NBQ2,DQ2,ACQ2,BDCAQ2,AK4,E1(6),ADJQ2,
     8F,E,PQ,E1(1),RPD,RQD,
     9PXP,PYP,PZP,TOTFOR,PXQ,PYQ,PZQ,TOTFOR,
     1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
     2R1XQ,R1YQ,R1ZQ,R2XQ,R2YQ,R2ZQ,
     3L1(2),H1(2),TOFORP1,P1(2),BDCAP1O,D1(2),
     4L1(3),H1(3),TOFORP2,P1(3),BDCAP2O,D1(3),
     5L1(5),H1(5),TOFORQ1,P1(5),BDCAQ1O,D1(5),
     6L1(6),H1(6),TOFORQ2,P1(6),BDCAQ2O,D1(6),
     7L1(1),H1(1),DCAP,D1(1),
     8L1(4),H1(4),DCAQ,D1(4),
     9LI(I),DUMB,DUMB)
       CALL PLANCA(ISTEP,NCOMP,MQPA,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3DTOS,DTO,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,ALI(I),
     4DUMB,DUMB)
       CALL PLANCA(BISTEP,BNCOMP,MQPB,BNS,BNPS,BNPR,BNR,BPHIS1,
     1BPHIR1,BRS,BRPS,BRPR,BRR,BCB,BA,BV,BPB,BN,BEB,BFTT,
     2BB1SM,BPS,BES,BWDSM,BB1RM,BPR,BER,BWDRM,
     3DTOPA,DTO,SOPA,SOF,BCS,BLS,BFS,BCR,BLR,BFR,BD1,BL1,
     4BH1,BE1,BLI(I),DUMB,DUMB)
       DO 12 IE=1,6
```

```
12          ZL1(IE)=L1(IE)
            DO 13 IE=1,ISTEP
13              ZL1(IE+6)=AL1(IE)
                DO 14 IE=1,BISTEP
14                  ZL1(IE+6+ISTEP)=BL1(IE)
       CALL LIFE(ZL1,INCOMP,ZE1,ZNCOMP,ZLI(I),DUMB)
20    CONTINUE
      CALL CAP(DYN,ZLI,10,DTRANS,PTRANS)
1220  FORMAT('     TOTAL TRANSMISSION'/)
1221  FORMAT('     SPIRAL BEVEL UNIT'/)
1222  FORMAT('     PLANETARY UNIT'/)
      WRITE(1,1221)
      CALL DPLHE(DSB,PSP,LSB,HSB,ESB)
      WRITE(1,1222)
      CALL DPLHE(DPLAN,PPLAN,LPLAN,HPLAN,EPLAN)
      WRITE(1,1222)
      CALL DPLHE(BDPLAN,BPPLAN,BLPLAN,BHPLAN,BEPLAN)
      WRITE(1,1220)
      CALL DPLHE(DTRANS,PTRANS,LTRANS,HTRANS,ETRANS)
      STOP
      END
      SUBROUTINE DPBV
      INTEGER CASEP,CASEG,PTL,GTL
      REAL NP,NG,NBP1,NBP2,NBG1,NBG2,MG,MG1,LSB
      REAL L1(9),D1(9),E1(9),H1(9),P1(9),DYN(10),LI(10)
101   FORMAT('WHAT IS THE INPUT TORQUE OF THE RIGHT PINION')
102   FORMAT('WHAT IS THE INPUT TORQUE OF THE LEFT PINION')
103   FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
      WRITE(1,101)
      READ(1,*)TIR
      WRITE(1,102)
      READ(1,*)TIL
      WRITE(1,102)
      READ(1,*)SI
C
C      INPUT SPIRAL BEVEL GEAR GEOMETRY
C
       CALL DPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,E1(1),PG,
     1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
     2BDCAP1,RFP1,E1(2),ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,E1(3),
     3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,E1(5),
     4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,E1(6),MG,GAMMA1,GAMMA,ZZ,
     5ZZ1,DP,DG,RPD,RP,RGD,RG,HK,ADG,AOP,HT,BOG,BOP,PD,
     6ADJP1,ADJP2,ADJG1,ADJG2,ZIP)
C
```

```
      E1(4)=E1(1)
      E1(7)=E1(1)
      E1(8)=E1(2)
      E1(9)=E1(3)
      P1(1)=PG
      P1(4)=PG
      P1(7)=PG
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION
C
      TOF=TIR*MG+TIL*MG
      SOF=SI/MG
      MG1=1.0
C
C     CALCULATE LIVES AND DYNAMIC CAPACITIES OF SPIRAL BEVEL
C     COMPONENTS AND LIFE OF THE TRANSMISSION
C
      CALL DPBVCA(
     1TIR,TIL,TOF,SI,SOF,MG,MG1,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,ZIP,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
     8F,E,PG,E1(1),RPD,RGD,
     9PXPR,PYPR,PZPR,TOTFORR,PXGR,PYGR,PZGR,TOTFORGE,
     9PXPL,PYPL,PZPL,TOTFORL,PXGL,PYGL,PZGL,TOTFORGE,
     1R1XPR,R1YPR,R1ZPR,R2XPR,R2YPR,R2ZPR,
     1R1XPL,R1YPL,R1ZPL,R2XPL,R2YPL,R2ZPL,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1R,P1(2),BDCAP1OR,D1(2),
     4L1(3),H1(3),TOFORP2R,P1(3),BDCAP2OR,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
     7L1(1),H1(1),DCAPR,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     *L1(7),H1(7),DCAPL,D1(7),
     *L1(8),H1(8),TOFORP1L,P1(8),BDCAP1OL,D1(8),
     *L1(9),H1(9),TOFORP2L,P1(9),BDCAP1OL,D1(9),
     9LSB,HSB,ESB)
C
C     PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS
C
```

```
       CALL  DPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOF, ROT, TIR, TIL, TOF,
      1THETA, NP, GAMMA, DP, RPD, AOP, BOP,
      2PXPR, PYPR, PZPR, TOTFORR, DCAPR, CASEP, AP, BP,
      3R1XPR, R1YPR, R1ZPR, TOFORP1R, BDCAP1OR,
      4R2XPR, R2YPR, R2ZPR, TOFORP2R, BDCAP2OR,
      2PXPL, PYPL, PZPL, TOTFORL, DCAPL, CASEP, AP, BP,
      3R1XPL, R1YPL, R1ZPL, TOFORP1L, BDCAP1OL,
      4R2XPL, R2YPL, R2ZPL, TOFORP2L, BDCAP2OL,
      5NG, ZZ, DG, RGD, AOG, BOG,
      6PXGR, PYGR, PZGR, TOTFORGE, DCAG, CASEG, AG, BG,
      6PXGL, PYGL, PZGL, TOTFORGE, DCAG, CASEG, AG, BG,
      7R1XG, R1YG, R1ZG, TOFORG1, BDCAG1O,
      8R2XG, R2YG, R2ZG, TOFORG2, BDCAG2O,
      9D1, P1, L1, H1, E1)
C
C      ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION
C
       DMIN=D1(1)
       DO 10 I=2,9
10         IF(D1(I).LT.DMIN)DMIN=D1(I)
           DELTATO=.1*DMIN
           DELTATI=0.5*DELTATO/MG
           DTIR=0.0
           DTIL=0.0
           DTO=0.0
C
C       START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT
C       OF TRANSMISSION DYNAMIC CAPACITY
C
           DO 20 I=1,10
               DTIR=DTIR+DELTATI
               DTIL=DTIL+DELTATI
               DTO=DTO+DELTATO
               DYN(I)=DTO
C
C      CALCULATE LIFE FOR EACH DYNAMIC CAPACITY
C
       CALL  DPBVCA(
      1DTIR, DTIL, DTO, SI, SOF, MG, MG1, NP, NG,
      2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1, ZIP,
      3PTL, AP, BP, RP, GTL, AG, BG, RG,
      4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
      5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
      6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
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     7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
     8F, E, PG, E1(1), RPD, RGD,
     9PXPR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE,
     9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,
     1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
     1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
     2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
     3L1(2), H1(2), TOFORP1R, P1(2), BDCAP1OR, D1(2),
     4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2OR, D1(3),
     5L1(5), H1(5), TOFORG1, P1(5), BDCAG1O, D1(5),
     6L1(6), H1(6), TOFORG2, P1(6), BDCAG2O, D1(6),
     7L1(1), H1(1), DCAPR, D1(1),
     8L1(4), H1(4), DCAG, D1(4),
     *L1(7), H1(7), DCAPL, D1(7),
     *L1(8), H1(8), TOFORP1L, P1(8), BDCAP1OL, D1(8),
     *L1(9), H1(9), TOFORP2L, P1(9), BDCAP1OL, D1(9),
     9LI(I), HSB1, ESB1)
20    CONTINUE
C
C     CALCULATE DYNAMIC CAPACITY AND LOAD LIFE EXPONENT FOR
C      TRANSMISSION
      CALL CAP(DYN, LI, 10, DSB, PSP)
C
C    PRINT OUT LIFE AND DYNAMIC CAPACITY OF TRANSMISSION
C
      WRITE(1, 1220)
1220  FORMAT('     TOTAL TRANSMISSION'/)
      CALL DPLHE(DSB, PSP, LSB, HSB, ESB)
      STOP
      END

      SUBROUTINE SBDBPL
       INTEGER CASEP, CASEG, PTL, GTL
       INTEGER CCASEP, CCASEG, CPTL, CGTL
      REAL NP, NG, NBP1, NBP2, NBG1, NBG2, MG, LSB
      REAL L1(9), D1(9), E1(9), H1(9), P1(9), DYN(10), LI(10)
      REAL CNP, CNG, CNBP1, CNBP2, CNBG1, CNBG2, CMG, CLSB
      REAL CL1(6), CD1(6), CE1(6), CH1(6), CP1(6), CDYN(10), CLI(10)
      REAL DL1(6), DH1(6), DD1(6)
      REAL NS, NPS, NPR, NR, N, LS, LR, LPLAN
      REAL NCOMP(5), AD1(5), AP1(5), AL1(5), AH1(5), AE1(5), ALI(10)
      REAL MGS, MGP, ZNCOMP(26), ZE1(26), ZL1(26), LTRANS, ZLI(10)
101   FORMAT('WHAT IS THE INPUT TORQUE OF THE RIGHT PINION')
102   FORMAT('WHAT IS THE INPUT TORQUE OF THE LEFT PINION')
103   FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
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```
      WRITE(1,101)
      READ(1,*)CTIR
      WRITE(1,102)
      READ(1,*)CTIL
      WRITE(1,103)
      READ(1,*)CSI
C
C     READ IN VALUES OF THE SPIRAL BEVEL UNIT
C
      CALL SPBVIN(CNP,CNG,CAO,CPHE,CF,CPHSI,CROT,CSPR,CTHETA,
     1CE,CE1(1),CPG,CPHE1,CPHSI1,CTHETA1,CCASEP,CPTL,CCAP,CBP,
     2CITYPEP1,CNBP1,CDP1,CACP1,CAK1,CBDCAP1,CRFP1,CE1(2),
     3CITYPEP2,CNBP2,CDP2,CACP2,CAK2,CBDCAP2,CRFP2,CE1(3),
     4CCASEG,CGTL,CAG,CBG,CITYPEG1,CNBG1,CDG1,CACG1,CAK3,
     5CBDCAG1,CRFG1,CE1(5),CITYPEG2,CNBG2,CDG2,CACG2,CAK4,
     6CBDCAG2,CRFG2,CE1(6),CMG,CGAMMA1,CGAMMA,CZZ,CZZ1,CDP,
     7CDG,CRPD,CRP,CRGD,CRG,CHK,CAOG,CAOP,CHT,CBOG,CBOP,CPITCH,
     8CADJP1,CADJP2,CADJG1,CADJG2)
C
C
      CE1(4)=CE1(1)
      CP1(1)=CPG
      CP1(4)=CPG
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF SPIRAL BEVEL UNIT
C
      TIR=CTIR*CMG
      TIL=CTIL*CMG
      SI=CSI/CMG
C
C     INPUT SPIRAL BEVEL GEAR GEOMETRY
C
      CALL DPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,E1(1),PG,
     1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
     2BDCAP1,RFP1,E1(2),ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,E1(3),
     3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,E1(5),
     4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,E1(6),MG,GAMMA1,GAMMA,ZZ,
     5ZZ1,DP,DG,RPD,RP,RGD,RG,HK,AOG,AOP,HT,BOG,BOP,PD,
     6ADJP1,ADJP2,ADJG1,ADJG2,ZIP)
C
      E1(4)=E1(1)
      E1(7)=E1(1)
      E1(8)=E1(2)
      E1(9)=E1(3)
      P1(1)=PG
```

```
      P1(4)=PG
      P1(7)=PG
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION
C
      TOS=TIR*MG+TIL*MG
      SOS=SI/MG
C
C     READ IN VALUES OF PLANETARY UNIT
C
      CALL PLANIN(CB,A,V,EB,PB,N,NCOMP,PDS,PDR,NS,PHIS,PHIS1,
     1PHIR,PHIR1,WDSM,ES,PS,B1SM,ISTEP,NPS,NPR,NR,WDRM,ER,PR,B1RM,
     2RPR,RPS,RR,RS)
      AP1(1)=PB
      AP1(2)=PS
      AP1(3)=PR
      AP1(4)=PS
      AP1(5)=PR
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT
C
      TOF=TOS*(1.+(RR*RPS)/(RS*RPR))
      SOF=SOS/(1.+(RR*RPS)/(RS*RPR))
      MGS=(1.+(RR*RPS)/(RS*RPR))
      CMGS=MGS*NG/NP
      MGP=1.0
      INCOMP=21+ISTEP
      DO 5 IN=1,21
5     ZNCOMP(IN)=1.0
      DO 6 IN=1,ISTEP
6     ZNCOMP(IN+21)=NCOMP(IN)
C
C     CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C     CALCULATE LIFE OF SPIRAL BEVEL UNIT
C
      CALL SPBVCA(
     1CTIR,TOF,CSI,SOF,CMG,CMGS,CNP,CNG,
     2CAO,CGAMMA1,CROT,CSPR,CPHE1,CPHSI1,CZZ1,
     3CPTL,CCAP,CBP,CRP,CGTL,CAG,CBG,CRG,
     4CITYPEP1,CRFP1,CNBP1,CDP1,CACP1,CBDCAP1,CAK1,CE1(2),CADJP1,
     5CITYPEP2,CRFP2,CNBP2,CDP2,CACP2,CBDCAP2,CAK2,CE1(3),CADJP2,
     6CITYPEG1,CRFG1,CNBG1,CDG1,CACG1,CBDCAG1,CAK3,CE1(5),CADJG1,
     7CITYPEG2,CRFG2,CNBG2,CDG2,CACG2,CBDCAG2,CAK4,CE1(6),CADJG2
     8CF,CE,CPG,CE1(1),CRPD,CRGD,
     9CPXP,CPYP,CPZP,CTOTFOR,CPXG,CPYG,CPZG,CTOTFOR,
```

```
      1CR1XP,CR1YP,CR1ZP,CR2XP,CR2YP,CR2ZP,
      2CR1XQ,CR1YQ,CR1ZQ,CR2XQ,CR2YQ,CR2ZQ,
      3CL1(2),CH1(2),CTOFORP1,CP1(2),CBDCAP10,CD1(2),
      4CL1(3),CH1(3),CTOFORP2,CP1(3),CBDCAP20,CD1(3),
      5CL1(5),CH1(5),CTOFORQ1,CP1(5),CBDCAQ10,CD1(5),
      6CL1(6),CH1(6),CTOFORQ2,CP1(6),CBDCAQ20,CD1(6),
      7CL1(1),CH1(1),CDCAP,CD1(1),
      8CL1(4),CH1(4),CDCAQ,CD1(4),
      9CLSB,CHSB,CESB)
C
C      PRINT OUT RESULTS FOR SPIRAL BEVEL UNIT
C
       CALL SPBVOT(CPD,CPHE,CPHSI,CSPR,CF,CAO,CSI,CSOS,CROT,
      1CTIR,TIR,CTHETA,CNP,CGAMMA,CDP,CRPD,CAOP,CBOP,CPITCH,
      2CPXP,CPYP,CPZP,CTOTFOR,CDCAP,CCASEP,CCAP,CBP,
      3CR1XP,CR1YP,CR1ZP,CTOFORP1,CBDCAP10,
      4CR2XP,CR2YP,CR2ZP,CTOFORP2,CBDCAP20,
      5CNQ,CZZ,CDQ,CRQD,CAOQ,CBOQ,
      6CPXQ,CPYQ,CPZQ,CTOTFOR,CDCAQ,CCASEQ,CAQ,CBQ,
      7CR1XQ,CR1YQ,CR1ZQ,CTOFORQ1,CBDCAQ10,
      8CR2XQ,CR2YQ,CR2ZQ,CTOFORQ2,CBDCAQ20,
      9CD1,CP1,CL1,CH1,CE1)
C
C      CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C      CALCULATE LIFE OF SPIRAL BEVEL UNIT
C
       CALL SPBVCA(
      1CTIL,TOF,CSI,SOF,CMQ,CMQS,CNP,CNQ,
      2CAO,CGAMMA1,CROT,CSPR,CPHE1,CPHSI1,CZZ1,
      3CPTL,CCAP,CBP,CRP,CQTL,CAQ,CBQ,CRQ,
      4CITYPEP1,CRFP1,CNBP1,CDP1,CACP1,CBDCAP1,CAK1,CE1(2),CADJP1,
      5CITYPEP2,CRFP2,CNBP2,CDP2,CACP2,CBDCAP2,CAK2,CE1(3),CADJP2,
      6CITYPEQ1,CRFQ1,CNBQ1,CDQ1,CACQ1,CBDCAQ1,CAK3,CE1(5),CADJQ1,
      7CITYPEQ2,CRFQ2,CNBQ2,CDQ2,CACQ2,CBDCAQ2,CAK4,CE1(6),CADJQ2,
      8CF,CE,CPQ,CE1(1),CRPD,CRQD,
      9DPXP,DPYP,DPZP,DTOTFOR,DPXQ,DPYQ,DPZQ,DTOTFOR,
      1DR1XP,DR1YP,DR1ZP,DR2XP,DR2YP,DR2ZP,
      2DR1XQ,DR1YQ,DR1ZQ,DR2XQ,DR2YQ,DR2ZQ,
      3DL1(2),DH1(2),DTOFORP1,CP1(2),DBDCAP10,DD1(2),
      4DL1(3),DH1(3),DTOFORP2,CP1(3),DBDCAP20,DD1(3),
      5DL1(5),DH1(5),DTOFORQ1,CP1(5),DBDCAQ10,DD1(5),
      6DL1(6),DH1(6),DTOFORQ2,CP1(6),DBDCAQ20,DD1(6),
      7DL1(1),DH1(1),DDCAP,DD1(1),
      8DL1(4),DH1(4),DDCAQ,DD1(4),
      9DLSB,DHSB,DESB)
```

```
C
C     PRINT OUT RESULTS FOR SPIRAL BEVEL UNIT
C
      CALL SPBVOT(CPD,CPHE,CPHSI,CSPR,CF,CAO,CSI,CSOS,CROT,
     1CTIL,CTOS,CTHETA,CNP,CGAMMA,CDP,CRPD,CAOP,CBOP,CPITCH,
     2DPXP,DPYP,DPZP,DTOTFOR,DDCAP,CCASEP,CCAP,CBP,
     3DR1XP,DR1YP,DR1ZP,DTOFORP1,DBDCAP1O,
     4DR2XP,DR2YP,DR2ZP,DTOFORP2,DBDCAP2O,
     5CNG,CZZ,CDG,CRGD,CAOG,CBOG,
     6DPXG,DPYG,DPZG,DTOTFOR,DDCAG,CCASEG,CAG,CBG,
     7DR1XG,DR1YG,DR1ZG,DTOFORG1,DBDCAG1O,
     8DR2XG,DR²YG,DR2ZG,DTOFORG2,DBDCAG2O,
     9DD1,CP1,DL1,DH1,CE1)
C
C     CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C     CALCULATE LIFE OF SPIRAL BEVEL UNIT
C
      CALL DPBVCA(
     1TIR,TIL,TOF,SI,SOF,MG,MGS,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,ZIP,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
     8F,E,PG,E1(1),RPD,RGD,
     9PXPR,PYPR,PZPR,TOTFORR,PXGR,PYGR,PZGR,TOTFORGE,
     9PXPL,PYPL,PZPL,TOTFORL,PXGL,PYGL,PZGL,TOTFORGE,
     1R1XPR,R1YPR,R1ZPR,R2XPR,R2YPR,R2ZPR,
     1R1XPL,R1YPL,R1ZPL,R2XPL,R2YPL,R2ZPL,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1R,P1(2),BDCAP1OR,D1(2),
     4L1(3),H1(3),TOFORP2R,P1(3),BDCAP2OR,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
     7L1(1),H1(1),DCAPR,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     *L1(7),H1(7),DCAPL,D1(7),
     *L1(8),H1(8),TOFORP1L,P1(8),BDCAP1OL,D1(8),
     *L1(9),H1(9),TOFORP2L,P1(9),BDCAP1OL,D1(9),
     9LSB,HSB,ESB)
C
C     PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS
C
```

```
      CALL DPBVOT(PD,PHE,PHSI,SPR,F,AO,SI,SOF,ROT,TIR,TIL,TOF,
     1THETA,NP,GAMMA,DP,RPD,AOP,BOP,
     2PXPR,PYPR,PZPR,TOTFORR,DCAPR,CASEP,AP,BP,
     3R1XPR,R1YPR,R1ZPR,TOFORP1R,BDCAP1OR,
     4R2XPR,R2YPR,R2ZPR,TOFORP2R,BDCAP2OR,
     2PXPL,PYPL,PZPL,TOTFORL,DCAPL,CASEP,AP,BP,
     3R1XPL,R1YPL,R1ZPL,TOFORP1L,BDCAP1OL,
     4R2XPL,R2YPL,R2ZPL,TOFORP2L,BDCAP2OL,
     5NG,ZZ,DG,RGD,AOG,BOG,
     6PXGR,PYGR,PZGR,TOTFORGE,DCAG,CASEG,AG,BG,
     6PXGL,PYGL,PZGL,TOTFORGE,DCAG,CASEG,AG,BG,
     7R1XG,R1YG,R1ZG,TOFORG1,BDCAG1O,
     8R2XG,R2YG,R2ZG,TOFORG2,BDCAG2O,
     9D1,P1,L1,H1,E1)
C
C     CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C     CALCULATE LIFE OF PLANETARY UNIT
C
      CALL PLANCA(ISTEP,NCOMP,MGP,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3TOS,TOF,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,
     4LPLAN,HPLAN,EPLAN)
C
C     PRINT OUT RESULTS FOR THE PLANETARY UNIT
C
      CALL PLANOT(ISTEP,N,V,CB,FB,NS,PDS,PHIS,WDSM,B1SM,FS,
     1NR,PDR,PHIR,WDRM,B1RM,FR,NP,NPS,NPR,TOS,TOF,SOS,SOF,FTT,
     2AD1,AP1,AL1,AH1,AE1)
C
C     DEFINE TRANSMISSION LIFE ARRAYS
C
      DO 50 IE=1,6
          ZE1(IE)=CE1(IE)
          ZE1(IE+6)=CE1(IE)
          ZL1(IE)=CL1(IE)
50        ZL1(IE+6)=DL1(IE)
      DO 8 IE=1,9
          ZE1(IE+12)=E1(IE)
8         ZL1(IE+12)=L1(IE)
          DO 9 IE=1,ISTEP
              ZE1(IE+21)=AE1(IE)
9             ZL1(IE+21)=AL1(IE)
       CALL LIFE(ZL1,INCOMP,ZE1,ZNCOMP,LTRANS,ETRANS)
```

```
      HTRANS=LTRANS*16666.667/SOF
C
C     ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION
C
      CDMIN=CD1(1)
      DO 51 I=2,6
51    IF(CD1(I).LT.CDMIN)CDMIN=CD1(I)
      DELTATO=.1*CDMIN
      DELTATI=0.5*NP/NG*DELTATO/MG/MGS
      DTO=0.0
      DTI=0.0
      DO 52 I=1,10
          DTI=DTI+DELTATI
          DTO=DTO+DELTATO
          DYN(I)=DTO
      CALL SPBVCA(
     1DTI,TOF,CSI,SOF,CMG,CMGS,CNP,CNG,
     2CAO,CGAMMA1,CROT,CSPR,CPHE1,CPHSI1,CZZ1,
     3CPTL,CCAP,CBP,CRP,CGTL,CAG,CBG,CRG,
     4CITYPEP1,CRFP1,CNBP1,CDP1,CACP1,CBDCAP1,CAK1,CE1(2),CADJP1,
     5CITYPEP2,CRFP2,CNBP2,CDP2,CACP2,CBDCAP2,CAK2,CE1(3),CADJP2,
     6CITYPEG1,CRFG1,CNBG1,CDG1,CACG1,CBDCAG1,CAK3,CE1(5),CADJG1,
     7CITYPEG2,CRFG2,CNBG2,CDG2,CACG2,CBDCAG2,CAK4,CE1(6),CADJG2,
     8CF,CE,CPG,CE1(1),CRPD,CRGD,
     9CPXP,CPYP,CPZP,CTOTFOR,CPXG,CPYG,CPZG,CTOTFOR,
     1CR1XP,CR1YP,CR1ZP,CR2XP,CR2YP,CR2ZP,
     2CR1XG,CR1YG,CR1ZG,CR2XG,CR2YG,CR2ZG,
     3CL1(2),CH1(2),CTOFORP1,CP1(2),CBDCAP1O,CD1(2),
     4CL1(3),CH1(3),CTOFORP2,CP1(3),CBDCAP2O,CD1(3),
     5CL1(5),CH1(5),CTOFORG1,CP1(5),CBDCAG1O,CD1(5),
     6CL1(6),CH1(6),CTOFORG2,CP1(6),CBDCAG2O,CD1(6),
     7CL1(1),CH1(1),CDCAP,CD1(1),
     8CL1(4),CH1(4),CDCAG,CD1(4),
     9LI(I),DUMB,DUMB)
52    CONTINUE
      CALL CAP(DYN,LI,10,CDSB,CPSB)
C
C     ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION
C
      DMIN=D1(1)
      DO 21 I=2,9
21        IF(D1(I).LT.DMIN)DMIN=D1(I)
          DELTATO=.1*DMIN
          DELTATI=0.5*DELTATO/MG/MGS
          DTIR=0.0
```

```
          DTIL=0.0
          DTO=0.0
C
C       START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT
C       OF TRANSMISSION DYNAMIC CAPACITY
C
          DO 22 I=1,10
             DTIR=DTIR+DELTATI
             DTIL=DTIL+DELTATI
             DTO=DTO+DELTATO
             DYN(I)=DTO
C
C      CALCULATE LIFE FOR EACH DYNAMIC CAPACITY
C
       CALL DPBVCA(
      1DTIR,DTIL,DTO,SI,SOF,MG,MGS,NP,NG,
      2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,ZIP,
      3PTL,AP,BP,RP,GTL,AG,BG,RG,
      4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
      5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
      6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
      7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
      8F,E,PG,E1(1),RPD,RGD,
      9PXPR,PYPR,PZPR,TOTFORR,PXGR,PYGR,PZGR,TOTFORGE,
      9PXPL,PYPL,PZPL,TOTFORL,PXGL,PYGL,PZGL,TOTFORGE,
      1R1XPR,R1YPR,R1ZPR,R2XPR,R2YPR,R2ZPR,
      1R1XPL,R1YPL,R1ZPL,R2XPL,R2YPL,R2ZPL,
      2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
      3L1(2),H1(2),TOFORP1R,P1(2),BDCAP1OR,D1(2),
      4L1(3),H1(3),TOFORP2R,P1(3),BDCAP2OR,D1(3),
      5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
      6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
      7L1(1),H1(1),DCAPR,D1(1),
      8L1(4),H1(4),DCAG,D1(4),
      *L1(7),H1(7),DCAPL,D1(7),
      *L1(8),H1(8),TOFORP1L,P1(8),BDCAP1OL,D1(8),
      *L1(9),H1(9),TOFORP2L,P1(9),BDCAP1OL,D1(9),
      9LI(I),DUMB,DUMB)
 22     CONTINUE
        CALL CAP(DYN,LI,10,DSB,PSP)
C
C
C
C        START COUNTER FOR LOADS BETWEEEN 15 AND 100 PERCENT OF DYNAMIC
C        CAPACITY
```

```
C
      ADMIN=AD1(1)
      DO 23 I=2,ISTEP
23        IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
              DELTATO=.1*ADMIN
              DELTATOS=DELTATO/MGS
              DTO=0.0
              DTOS=0.0
                  DO 24 I=1,10
                      DTOS=DTOS+DELTATOS
                      DTO=DTO+DELTATO
                      DYN(I)=DTO
      CALL PLANCA(ISTEP,NCOMP,MGP,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3DTOS,DTO,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,ALI(I),DUMB,
     4DUMB)
24    CONTINUE
      CALL CAP(DYN,ALI,10,DPLAN,PPLAN)
C
C      START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C      CAPACITY
C
      IF(ADMIN.LT.DMIN)DMIN=ADMIN
      IF(CDMIN.LT.DMIN)DMIN=CDMIN
          DELTATO=.1*DMIN
          DELTATOS=DELTATO/MGS
          DELTATIR=DELTATOS/MG/2.
          DELTATIL=DELTATOS/MG/2.
          CDELTI=DELTATIR*CNP/CNG
          CTI=0.0
          DTIR=0.0
          DTIL=0.0
          DTOS=0.0
          DTO=0.0
          DO 20 I=1,10
              CTI=CTI+CDELTI
              DTIR=DTIR+DELTATIR
              DTIL=DTIL+DELTATIL
              DTOS=DTOS+DELTATOS
              DTO=DTO+DELTATO
              DYN(I)=DTO
C
C
```

```
C
       CALL SPBVCA(
      1CTI, DTO, CSI, SOF, CMQ, CMQS, CNP, CNQ,
      2CAO, CGAMMA1, CROT, CSPR, CPHE1, CPHSI1, CZZ1,
      3CPTL, CCAP, CBP, CRP, CQTL, CAQ, CBQ, CRQ,
      4CITYPEP1, CRFP1, CNBP1, CDP1, CACP1, CBDCAP1, CAK1, CE1(2), CADJP1,
      5CITYPEP2, CRFP2, CNBP2, CDP2, CACP2, CBDCAP2, CAK2, CE1(3), CADJP2,
      6CITYPEQ1, CRFQ1, CNBQ1, CDQ1, CACQ1, CBDCAQ1, CAK3, CE1(5), CADJQ1,
      7CITYPEQ2, CRFQ2, CNBQ2, CDQ2, CACQ2, CBDCAQ2, CAK4, CE1(6), CADJQ2,
      8CF, CE, CPQ, CE1(1), CRPD, CRQD,
      9CPXP, CPYP, CPZP, CTOTFOR, CPXQ, CPYQ, CPZQ, CTOTFOR,
      1CR1XP, CR1YP, CR1ZP, CR2XP, CR2YP, CR2ZP,
      2CR1XQ, CR1YQ, CR1ZQ, CR2XQ, CR2YQ, CR2ZQ,
      3CL1(2), CH1(2), CTOFORP1, CP1(2), CBDCAP1O, CD1(2),
      4CL1(3), CH1(3), CTOFORP2, CP1(3), CBDCAP2O, CD1(3),
      5CL1(5), CH1(5), CTOFORQ1, CP1(5), CBDCAQ1O, CD1(5),
      6CL1(6), CH1(6), CTOFORQ2, CP1(6), CBDCAQ2O, CD1(6),
      7CL1(1), CH1(1), CDCAP, CD1(1),
      8CL1(4), CH1(4), CDCAQ, CD1(4),
      9DUMB, DUMB, DUMB)
C
       CALL DPBVCA(
      1DTIR, DTIL, DTO, SI, SOF, MQ, MQS, NP, NQ,
      2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1, ZIP,
      3PTL, AP, BP, RP, QTL, AQ, BQ, RQ,
      4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
      5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
      6ITYPEQ1, RFQ1, NBQ1, DQ1, ACQ1, BDCAQ1, AK3, E1(5), ADJQ1,
      7ITYPEQ2, RFQ2, NBQ2, DQ2, ACQ2, BDCAQ2, AK4, E1(6), ADJQ2,
      8F, E, PQ, E1(1), RPD, RQD,
      9PXPR, PYPR, PZPR, TOTFORR, PXQR, PYQR, PZQR, TOTFORQE,
      9PXPL, PYPL, PZPL, TOTFORL, PXQL, PYQL, PZQL, TOTFORQE,
      1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
      1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
      2R1XQ, R1YQ, R1ZQ, R2XQ, R2YQ, R2ZQ,
      3L1(2), H1(2), TOFORP1R, P1(2), BDCAP1OR, D1(2),
      4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2OR, D1(3),
      5L1(5), H1(5), TOFORQ1, P1(5), BDCAQ1O, D1(5),
      6L1(6), H1(6), TOFORQ2, P1(6), BDCAQ2O, D1(6),
      7L1(1), H1(1), DCAPR, D1(1),
      8L1(4), H1(4), DCAQ, D1(4),
      *L1(7), H1(7), DCAPL, D1(7),
      *L1(8), H1(8), TOFORP1L, P1(8), BDCAP1OL, D1(8),
      *L1(9), H1(9), TOFORP2L, P1(9), BDCAP1OL, D1(9),
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```
     9DUMB, DUMB, DUMB)
      CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1,
     1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
     2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
     3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, DUMB, DUMB,
     4DUMB)
      DO 54 IE=1,6
          ZL1(IE)=CL1(IE)
54        ZL1(IE+6)=CL1(IE)
      DO 12 IE=1,9
          ZE1(IE+12)=E1(IE)
12        ZL1(IE+12)=L1(IE)
          DO 13 IE=1,ISTEP
              ZE1(IE+21)=AE1(IE)
13            ZL1(IE+21)=AL1(IE)
       CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, ZLI(I), DUMB)
20    CONTINUE
      CALL CAP(DYN, ZLI, 10, DTRANS, PTRANS)
1220  FORMAT('     TOTAL TRANSMISSION'/)
1221  FORMAT('     SPIRAL BEVEL UNIT'/)
1222  FORMAT('     PLANETARY UNIT'/)
      WRITE(1,1221)
      CALL DPLHE(CDSB, CPSB, CLSB, CHSB, CESB)
      WRITE(1,1221)
      CALL DPLHE(CDSB, CPSB, DLSB, DHSB, DESB)
      WRITE(1,1221)
      CALL DPLHE(DSB, PSP, LSB, HSB, ESB)
      WRITE(1,1222)
      CALL DPLHE(DPLAN, PPLAN, LPLAN, HPLAN, EPLAN)
      WRITE(1,1220)
      CALL DPLHE(DTRANS, PTRANS, LTRANS, HTRANS, ETRANS)
      STOP
      END
      SUBROUTINE PLAN
      REAL NS, NPS, NPR, NR, N, LS, LR, LPLAN
      REAL NCOMP(5), D1(5), P1(5), L1(5), H1(5), E1(5), MG1, LI(10), DYN(10)
C
C     CB        DYNAMIC CAPACITY OF THE BEARINGS
C     A         LIFE ADJUSTMENT FACTOR OF THE BEARINGS
C     EB        WEIBULL EXPONENT OF THE BEARINGS
C     PB        LOAD LIFE EXPONENT OF THE BEARINGS
C     N         NUMBER OF PLANETARY GEARS
C     NCOMP(1)  NUMBER OF PLANET BEARINGS
C     NCOMP(2)  NUMBER OF SUN GEARS
C     NCOMP(3)  NUMBER OF RING GEARS
```

```
C       NCOMP(4) NUMBER OF PLANET-SUN GEARS
C       NCOMP(5) NUMBER OF PLANET-RING GEARS
C       PDS      PITCH OF PLANET-SUN MESH
C       PDR      PITCH OF PLANET-RING MESH
C       NS       NUMBER OF SUN GEAR TEETH
C       NPS      NUMBER OF PLANET-SUN GEAR TEETH
C       NPR      NUMBER OF PLANET-RING GEAR TEETH
C       NR       NUMBER OF RING GEAR TEETH
C       PHIS     PRESSURE ANGLE OF SUN GEAR (DEG)
C       PHIS1    PRESSURE ANGLE OF SUN GEAR (RAD)
C       PHIR     PRESSURE ANGLE OF RING GEAR (DEG)
C       PHIR1    PRESSURE ANGLE OF RING GEAR (RAD)
C       WDSM     WIDTH OF THE SUN GEAR MESH
C       WDRM     WIDTH OF THE RING GEAR MESH
C       ES       WEIBULL EXPONENT OF THE SUN GEAR MESH
C       ER       WEIBULL EXPONENT OF THE RIN GEAR MESH
C       PS       LOAD-LIFE EXPONENT OF THE SUN GEAR MESH
C       PR       LOAD-LIFE EXPONENT OF THE RING GEAR MESH
C       B1SM     MATERIAL CONSTANT OF THE SUN GEAR MESH
C       B1RM     MATERIAL CONSTANT OF THE RING GEAR MESH
C       RS       RADIUS OF THE SUN GEAR
C       RPS      RADIUS OF THE PLANET-SUN GEAR
C       RPR      RADIUS OF THE PLANET-RING GEAR
C       RR       RADIUS OF THE RING EGAR
C       ISTEP    NUMBER OF COMPONENTS IN THE PLANETARY
C                = 4 UNSTEPPED PLANETARY UNIT
C                = 5 STEPPED PALETARY UNIT
C
C       INPUT TORQUE AND SPEED
C
101     FORMAT('WHAT IS THE INPUT TORQUE OF THE TRANSMISSION')
102     FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
        WRITE(1,101)
        READ(1,*)TI
        WRITE(1,102)
        READ(1,*)SI
        CALL PLANIN(CB,A,V,EB,PB,N,NCOMP,PDS,PDR,NS,PHIS,PHIS1,
       1PHIR,PHIR1,WDSM,ES,PS,B1SM,ISTEP,NPS,NPR,NR,WDRM,ER,PR,B1RM,
       2RPR,RPS,RR,RS)
        P1(1)=PB
        P1(2)=PS
        P1(3)=PR
        P1(4)=PS
        P1(5)=PR
        MG1=1.0
```

```
      TOF=TI*(1.+(RR*RPS)/(RS*RPR))
      SOF=SI/(1.+(RR*RPS)/(RS*RPR))
C
C
C
      CALL PLANCA(ISTEP,NCOMP,MQ1,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3TI,TOF,SI,SOF,CS,LS,FS,CR,LR,FR,D1,L1,H1,E1,LPLAN,HPLAN,EPLAN)
C
C

C
      CALL PLANOT(ISTEP,N,V,CB,FB,NS,PDS,PHIS,WDSM,B1SM,FS,
     1NR,PDR,PHIR,WDRM,B1RM,FR,NP,NPS,NPR,TI,TOF,SI,SOF,FTT,
     2D1,P1,L1,H1,E1)
      DMIN=D1(1)
      DO 10 I=2,ISTEP
10    IF(D1(I).LT.DMIN)DMIN=D1(I)
      DELTATO=.1*DMIN
      DELTATI=DELTATO/(1.+(RR*RPS)/(RS*RPR))
      DTI=0.0
      DTO=0.0
      DO 20 I=1,10
           DTI=DTI+DELTATI
           DTO=DTO+DELTATO
           DYN(I)=DTO
      CALL PLANCA(ISTEP,NCOMP,MQ1,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3DTI,DTO,SI,SOF,CS,LS,FS,CR,LR,FR,D1,L1,H1,E1,LI(I),DUMB,DUMB)
20     CONTINUE
      CALL CAP(DYN,LI,10,DPLAN,PPLAN)
      WRITE(1,1000)
1000  FORMAT('     TOTAL TRANSMISSION'/)
      CALL DPLHE(DPLAN,PPLAN,LPLAN,HPLAN,EPLAN)
      STOP
      END
      SUBROUTINE DBPL
      INTEGER CASEP,CASEQ,PTL,QTL
      REAL NP,NQ,NBP1,NBP2,NBQ1,NBQ2,MQ,LSB
      REAL L1(9),D1(9),E1(9),H1(9),P1(9),DYN(10),LI(10)
      REAL NS,NPS,NPR,NR,N,LS,LR,LPLAN
      REAL NCOMP(5),AD1(5),AP1(5),AL1(5),AH1(5),AE1(5),ALI(10)
      REAL MQS,MQP,ZNCOMP(14),ZE1(14),ZL1(14),LTRANS,ZLI(10)
```

```
101   FORMAT('WHAT IS THE INPUT TORQUE OF THE RIGHT PINION')
102   FORMAT('WHAT IS THE INPUT TORQUE OF THE LEFT PINION')
103   FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
      WRITE(1,101)
      READ(1,*)TIR
      WRITE(1,102)
      READ(1,*)TIL
      WRITE(1,103)
      READ(1,*)SI
C
C     INPUT SPIRAL BEVEL GEAR GEOMETRY
C
      CALL DPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,E1(1),PG,
     1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
     2BDCAP1,RFP1,E1(2),ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,E1(3),
     3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,E1(5),
     4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,E1(6),MG,GAMMA1,GAMMA,ZZ,
     5ZZ1,DP,DG,RPD,RP,RGD,RG,HK,AOG,AOP,HT,BOG,BOP,PD,
     6ADJP1,ADJP2,ADJG1,ADJG2,ZIP)
C
      E1(4)=E1(1)
      E1(7)=E1(1)
      E1(8)=E1(2)
      E1(9)=E1(3)
      P1(1)=PG
      P1(4)=PG
      P1(7)=PG
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION
C
      TOS=TIR*MG+TIL*MG
      SOS=SI/MG
C
C     READ IN VALUES OF PLANETARY UNIT
C
      CALL PLANIN(CB,A V,EB,PB,N,NCOMP,PDS,PDR,NS,PHIS,PHIS1,
     1PHIR,PHIR1,WDSM,ES,PS,B1SM,ISTEP,NPS,NPR,NR,WDRM,ER,PR,B1RM,
     2RPR,RPS,RR,RS)
      AP1(1)=PB
      AP1(2)=PS
      AP1(3)=PR
      AP1(4)=PS
      AP1(5)=PR
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT
```

```
C
      TOF=TOS*(1.+(RR*RPS)/(RS*RPR))
      SOF=SOS/(1.+(RR*RPS)/(RS*RPR))
      MGS=(1.+(RR*RPS)/(RS*RPR))
      MGP=1.0
      INCOMP=9+ISTEP
      DO 5 IN=1,9
5     ZNCOMP(IN)=1.0
      DO 6 IN=1,ISTEP
6     ZNCOMP(IN+9)=NCOMP(IN)
C
C     CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C     CALCULATE LIFE OF SPIRAL BEVEL UNIT
C

      CALL DPBVCA(
     1TIR,TIL,TOF,SI,SOF,MG,MGS,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,ZIP,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
     8F,E,PG,E1(1),RPD,RGD,
     9PXPR,PYPR,PZPR,TOTFORR,PXGR,PYGR,PZGR,TOTFORGE,
     9PXPL,PYPL,PZPL,TOTFORL,PXGL,PYGL,PZGL,TOTFORGE,
     1R1XPR,R1YPR,R1ZPR,R2XPR,R2YPR,R2ZPR,
     1R1XPL,R1YPL,R1ZPL,R2XPL,R2YPL,R2ZPL,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1R,P1(2),BDCAP1OR,D1(2),
     4L1(3),H1(3),TOFORP2R,P1(3),BDCAP2OR,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
     7L1(1),H1(1),DCAPR,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     *L1(7),H1(7),DCAPL,D1(7),
     *L1(8),H1(8),TOFORP1L,P1(8),BDCAP1OL,D1(8),
     *L1(9),H1(9),TOFORP2L,P1(9),BDCAP1OL,D1(9),
     9LSB,HSB,ESB)
C
C     PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS
C

      CALL DPBVOT(PD,PHE,PHSI,SPR,F,AO,SI,SOF,ROT,TIR,TIL,TOF,
     1THETA,NP,GAMMA,DP,RPD,AOP,BOP,
```

```
     2PXPR, PYPR, PZPR, TOTFORR, DCAPR, CASEP, AP, BP,
     3R1XPR, R1YPR, R1ZPR, TOFORP1R, BDCAP1OR,
     4R2XPR, R2YPR, R2ZPR, TOFORP2R, BDCAP2OR,
     2PXPL, PYPL, PZPL, TOTFORL, DCAPL, CASEP, AP, BP,
     3R1XPL, R1YPL, R1ZPL, TOFORP1L, BDCAP1OL,
     4R2XPL, R2YPL, R2ZPL, TOFORP2L, BDCAP2OL,
     5NG, ZZ, DG, RGD, AOG, BOG,
     6PXGR, PYGR, PZGR, TOTFORGE, DCAG, CASEG, AG, BG,
     6PXGL, PYGL, PZGL, TOTFORGE, DCAG, CASEG, AG, BG,
     7R1XG, R1YG, R1ZG, TOFORG1, BDCAG1O,
     8R2XG, R2YG, R2ZG, TOFORG2, BDCAG2O,
     9D1, P1, L1, H1, E1)
C
C      CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C      CALCULATE LIFE OF PLANETARY UNIT
C
       CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1,
     1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
     2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
     3TOS, TOF, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1,
     4LPLAN, HPLAN, EPLAN)
C
C      PRINT OUT RESULTS FOR THE PLANETARY UNIT
C
       CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS,
     1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TOS, TOF, SOS, SOF, FTT,
     2AD1, AP1, AL1, AH1, AE1)
C
C      DEFINE TRANSMISSION LIFE ARRAYS
C
       DO 8 IE=1,9
            ZE1(IE)=E1(IE)
8           ZL1(IE)=L1(IE)
            DO 9 IE=1, ISTEP
                 ZE1(IE+9)=AE1(IE)
9                ZL1(IE+9)=AL1(IE)
        CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, LTRANS, ETRANS)
        HTRANS=LTRANS*16666.667/SOF
C
C      ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION
C
       DMIN=D1(1)
       DO 21 I=2,9
21          IF(D1(I).LT.DMIN)DMIN=D1(I)
            DELTATO=.1*DMIN
```

```
      DELTATI=0.5*DELTATO/MG/MGS
      DTIR=0.0
      DTIL=0.0
      DTO=0.0
C
C     START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT
C     OF TRANSMISSION DYNAMIC CAPACITY
C
      DO 22 I=1,10
          DTIR=DTIR+DELTATI
          DTIL=DTIL+DELTATI
          DTO=DTO+DELTATO
          DYN(I)=DTO
C
C    CALCULATE LIFE FOR EACH  DYNAMIC CAPACITY
C
     CALL DPBVCA(
    1DTIR,DTIL,DTO,SI,SOF,MG,MGS,NP,NG,
    2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,ZIP,
    3PTL,AP,BP,RP,GTL,AG,BG,RG,
    4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
    5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
    6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
    7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
    8F,E,PG,E1(1),RPD,RGD,
    9PXPR,PYPR,PZPR,TOTFORR,PXGR,PYGR,PZGR,TOTFORGE,
    9PXPL,PYPL,PZPL,TOTFORL,PXGL,PYGL,PZGL,TOTFORGE,
    1R1XPR,R1YPR,R1ZPR,R2XPR,R2YPR,R2ZPR,
    1R1XPL,R1YPL,R1ZPL,R2XPL,R2YPL,R2ZPL,
    2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
    3L1(2),H1(2),TOFORP1R,P1(2),BDCAP1OR,D1(2),
    4L1(3),H1(3),TOFORP2R,P1(3),BDCAP2OR,D1(3),
    5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
    6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
    7L1(1),H1(1),DCAPR,D1(1),
    8L1(4),H1(4),DCAG,D1(4),
    *L1(7),H1(7),DCAPL,D1(7),
    *L1(8),H1(8),TOFORP1L,P1(8),BDCAP1OL,D1(8),
    *L1(9),H1(9),TOFORP2L,P1(9),BDCAP1OL,D1(9),
    9LI(I),DUMB,DUMB)
22   CONTINUE
     CALL CAP(DYN,LI,10,DSB,PSP)
C
C
C
```

```
C        START COUNTER FOR LOADS BETWEEEN 15 AND 100 PERCENT OF DYNAMIC
C        CAPACITY
C
      ADMIN=AD1(1)
      DO 23 I=2, ISTEP
23        IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
              DELTATO=.1*ADMIN
              DELTATOS=DELTATO/MGS
              DTO=0.0
              DTOS=0.0
                  DO 24 I=1,10
                      DTOS=DTOS+DELTATOS
                      DTO=DTO+DELTATO
                      DYN(I)=DTO
      CALL PLANCA(ISTEP,NCOMP,MGP,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3DTOS,DTO,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,ALI(I),DUMB,
     4DUMB)
24    CONTINUE
      CALL CAP(DYN,ALI,10,DPLAN,PPLAN)
C
C        START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C        CAPACITY
C
      IF(ADMIN.LT.DMIN)DMIN=ADMIN
          DELTATO=.1*DMIN
          DELTATOS=DELTATO/MGS
          DELTATIR=DELTATOS/MG/2.
          DELTATIL=DELTATOS/MG/2.
          DTIR=0.0
          DTIL=0.0
          DTOS=0.0
          DTO=0.0
          DO 20 I=1,10
              DTIR=DTIR+DELTATIR
              DTIL=DTIL+DELTATIL
              DTOS=DTOS+DELTATOS
              DTO=DTO+DELTATO
              DYN(I)=DTO
C
C
C
      CALL DPBVCA(
     1DTIR,DTIL,DTO,SI,SOF,MG,MGS,NP,NG,
```

```
     2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1, ZIP,
     3PTL, AP, BP, RP, GTL, AG, BG, RG,
     4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
     5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
     6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
     7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
     8F, E, PG, E1(1), RPD, RGD,
     9PXPR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE,
     9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,
     1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
     1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
     2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
     3L1(2), H1(2), TOFORP1R, P1(2), BDCAP1OR, D1(2),
     4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2OR, D1(3),
     5L1(5), H1(5), TOFORG1, P1(5), BDCAG1O, D1(5),
     6L1(6), H1(6), TOFORG2, P1(6), BDCAG2O, D1(6),
     7L1(1), H1(1), DCAPR, D1(1),
     8L1(4), H1(4), DCAG, D1(4),
     *L1(7), H1(7), DCAPL, D1(7),
     *L1(8), H1(8), TOFORP1L, P1(8), BDCAP1OL, D1(8),
     *L1(9), H1(9), TOFORP2L, P1(9), BDCAP1OL, D1(9),
     9LI(I), DUMB, DUMB)
      CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1,
     1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
     2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
     3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB,
     4DUMB)
      DO 12 IE=1,9
12        ZL1(IE)=L1(IE)
          DO 13 IE=1,ISTEP
13            ZL1(IE+9)=AL1(IE)
       CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, ZLI(I), DUMB)
20    CONTINUE
      CALL CAP(DYN, ZLI, 10, DTRANS, PTRANS)
1220  FORMAT('     TOTAL TRANSMISSION'/)
1221  FORMAT('     SPIRAL BEVEL UNIT'/)
1222  FORMAT('     PLANETARY UNIT'/)
      WRITE(1,1221)
      CALL DPLHE(DSB, PSP, LSB, HSB, ESB)
      WRITE(1,1222)
      CALL DPLHE(DPLAN, PPLAN, LPLAN, HPLAN, EPLAN)
      WRITE(1,1220)
      CALL DPLHE(DTRANS, PTRANS, LTRANS, HTRANS, ETRANS)
      STOP
      END
```

```
      SUBROUTINE DBPLPL
      INTEGER CASEP,CASEG,PTL,GTL,BISTEP
      REAL NP,NG,NBP1,NBP2,NBG1,NBG2,MG,LSB
      REAL L1(9),D1(9),E1(9),H1(9),P1(9),DYN(10),LI(10)
      REAL NS,NPS,NPR,NR,N,LS,LR,LPLAN
      REAL NCOMP(5),AD1(5),AP1(5),AL1(5),AH1(5),AE1(5),ALI(10)
      REAL MGS,MGPA,MGPB,ZNCOMP(19),ZE1(19),ZL1(19),LTRANS,ZLI(10)
      REAL BNCOMP(5),BD1(5),BP1(5),BL1(5),BH1(5),BE1(5),BLI(10)
101   FORMAT('WHAT IS THE INPUT TORQUE OF THE RIGHT PINION')
102   FORMAT('WHAT IS THE INPUT TORQUE OF THE LEFT PINION')
103   FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
      WRITE(1,101)
      READ(1,*)TIR
      WRITE(1,102)
      READ(1,*)TIL
      WRITE(1,103)
      READ(1,*)SI
C
C     INPUT SPIRAL BEVEL GEAR GEOMETRY
C
      CALL DPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,E1(1),PG,
     1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
     2BDCAP1,RFP1,E1(2),ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,E1(3),
     3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,E1(5),
     4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,E1(6),MG,GAMMA1,GAMMA,ZZ,
     5ZZ1,DP,DG,RPD,RP,RGD,RG,HK,AOG,AOP,HT,BOG,BOP,PD,
     6ADJP1,ADJP2,ADJG1,ADJG2,ZIP)
C
      E1(4)=E1(1)
      E1(7)=E1(1)
      E1(8)=E1(2)
      E1(9)=E1(3)
      P1(1)=PG
      P1(4)=PG
      P1(7)=PG
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION
C
      TOS=TIR*MG+TIL*MG
      SOS=SI/MG
C
C     READ IN VALUES OF PLANETARY UNIT
C
      CALL PLANIN(CB,A,V,EB,PB,N,NCOMP,PDS,PDR,NS,PHIS,PHIS1,
     1PHIR,PHIR1,WDSM,ES,PS,B1SM,ISTEP,NPS,NPR,NR,WDRM,ER,PR,B1RM,
```

```
     2RPR,RPS,RR,RS)
      AP1(1)=PB
      AP1(2)=PS
      AP1(3)=PR
      AP1(4)=PS
      AP1(5)=PR
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT
C
      TOPA=TOS*(1.+(RR*RPS)/(RS*RPR))
      SOPA=SOS/(1.+(RR*RPS)/(RS*RPR))
C
C     READ IN VALUES OF PLANETARY UNIT
C
      CALL PLANIN(BCB,BA,BV,BEB,BPB,BN,BNCOMP,BPDS,BPDR,BNS,BPHIS,
     1BPHIS1,BPHIR,BPHIR1,BWDSM,BES,BPS,BB1SM,BISTEP,BNPS,
     2BNPR,BNR,BWDRM,BER,BPR,BB1RM,BRPR,BRPS,BRR,BRS)
      BP1(1)=BPB
      BP1(2)=BPS
      BP1(3)=BPR
      BP1(4)=BPS
      BP1(5)[illegible]R
C
C     CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT
C
      TOF=TOPA*(1.+(BRR*BRPS)/(BRS*BRPR))
      SOF=SOPA/(1.+(BRR*BRPS)/(BRS*BRPR))
      MGPA=(1.+(BRR*BRPS)/(BRS*BRPR))
      MGS=(1.+(RR*RPS)/(RS*RPR))*MGPA
      MGPB=1.0
      INCOMP=9+ISTEP+BISTEP
      DO 5 IN=1,9
5     ZNCOMP(IN)=1.0
      DO 6 IN=1,ISTEP
6     ZNCOMP(IN+9)=NCOMP(IN)
      IX=9+ISTEP
      DO 77 IN=1,BISTEP
77    ZNCOMP(IN+IX)=BNCOMP(IN)
C
C     CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C     CALCULATE LIFE OF SPIRAL BEVEL UNIT
C

      CALL DPBVCA(
     1TIR,TIL,TOF,SI,SOF,MG,MGS,NP,NG,
```

```
     2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1, ZIP,
     3PTL, AP, BP, RP, GTL, AG, BG, RG,
     4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
     5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
     6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
     7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
     8F, E, PG, E1(1), RPD, RGD,
     9PXPR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE,
     9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,
     1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
     1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
     2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
     3L1(2), H1(2), TOFORP1R, P1(2), BDCAP1OR, D1(2),
     4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2OR, D1(3),
     5L1(5), H1(5), TOFORG1, P1(5), BDCAG1O, D1(5),
     6L1(6), H1(6), TOFORG2, P1(6), BDCAG2O, D1(6),
     7L1(1), H1(1), DCAPR, D1(1),
     8L1(4), H1(4), DCAG, D1(4),
     *L1(7), H1(7), DCAPL, D1(7),
     *L1(8), H1(8), TOFORP1L, P1(8), BDCAP1OL, D1(8),
     *L1(9), H1(9), TOFORP2L, P1(9), BDCAP1OL, D1(9),
     9LSB, HSB, ESB)
C
C      PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS
C

      CALL DPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOF, ROT, TIR, TIL, TOF,
     1THETA, NP, GAMMA, DP, RPD, AOP, BOP,
     2PXPR, PYPR, PZPR, TOTFORR, DCAPR, CASEP, AP, BP,
     3R1XPR, R1YPR, R1ZPR, TOFORP1R, BDCAP1OR,
     4R2XPR, R2YPR, R2ZPR, TOFORP2R, BDCAP2OR,
     2PXPL, PYPL, PZPL, TOTFORL, DCAPL, CASEP, AP, BP,
     3R1XPL, R1YPL, R1ZPL, TOFORP1L, BDCAP1OL,
     4R2XPL, R2YPL, R2ZPL, TOFORP2L, BDCAP2OL,
     5NG, ZZ, DG, RGD, AOG, BOG,
     6PXGR, PYGR, PZGR, TOTFORGE, DCAG, CASEG, AG, BG,
     6PXGL, PYGL, PZGL, TOTFORGE, DCAG, CASEG, AG, BG,
     7R1XG, R1YG, R1ZG, TOFORG1, BDCAG1O,
     8R2XG, R2YG, R2ZG, TOFORG2, BDCAG2O,
     9D1, P1, L1, H1, E1)
C
C      CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C      CALCULATE LIFE OF PLANETARY UNIT
C
      CALL PLANCA(ISTEP, NCOMP, MGPA, NS, NPS, NPR, NR, PHIS1, PHIR1,
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```
     1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
     2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
     3TOS, TOF, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1,
     4LPLAN, HPLAN, EPLAN)
C
C      PRINT OUT RESULTS FOR THE PLANETARY UNIT
C
       CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS,
     1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TOS, TOF, SOS, SOF, FTT,
     2AD1, AP1, AL1, AH1, AE1)
C
C      CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C      CALCULATE LIFE OF PLANETARY UNIT
C
       CALL PLANCA(BISTEP, BNCOMP, MGPB, BNS, BNPS, BNPR, BNR,
     1BPHIS1, BPHIR1, BRS, BRPS, BRPR, BRR, BCB, BA, BV, BPB, BN, BEB,
     2BFTT, BB1SM, BPS, BES, BWDSM, BB1RM, BPR, BER, BWDRM,
     3TOPA, TOF, SOPA, SOF, BCS, BLS, BFS, BCR, BLR, BFR, BD1, BL1, BH1, BE1,
     4BLPLAN, BHPLAN, BEPLAN)
C
C      PRINT OUT RESULTS FOR THE PLANETARY UNIT
C
       CALL PLANOT(BISTEP, BN, BV, BCB, BFB, BNS, BPDS, BPHIS, BWDSM,
     1BB1SM, BFS, BNR, BPDR, BPHIR, BWDRM, BB1RM, BFR, BNP, BNPS, BNPR,
     2TOPA, TOF, SOPA, SOF, BFTT, BD1, BP1, BL1, BH1, BE1)
C
C      DEFINE TRANSMISSION LIFE ARRAYS
C
       DO 8 IE=1,9
           ZE1(IE)=E1(IE)
8          ZL1(IE)=L1(IE)
           DO 9 IE=1, ISTEP
               ZE1(IE+9)=AE1(IE)
9              ZL1(IE+9)=AL1(IE)
               DO 99 IE=1, BISTEP
                    ZE1(IE+9+ISTEP)=BE1(IE)
99                  ZL1(IE+9+ISTEP)=BL1(IE)
        CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, LTRANS, ETRANS)
        HTRANS=LTRANS*16666.667/SOF
C
C       START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C       CAPACITY
       DMIN=D1(1)
       DO 21 I=2,9
21         IF(D1(I).LT.DMIN)DMIN=D1(I)
```

```
      DELTATO=.1*DMIN
      DELTATI=0.5*DELTATO/MG/MGS
      DTIR=0.0
      DTIL=0.0
      DTO=0.0
C
C     START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT
C     OF TRANSMISSION DYNAMIC CAPACITY
C
      DO 22 I=1,10
         DTIR=DTIR+DELTATI
         DTIL=DTIL+DELTATI
         DTO=DTO+DELTATO
         DYN(I)=DTO
C
C     CALCULATE LIFE FOR EACH DYNAMIC CAPACITY
C
      CALL DPBVCA(
     1DTIR,DTIL,DTO,SI,SOF,MG,MGS,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,ZIP,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
     8F,E,PG,E1(1),RPD,RGD,
     9PXPR,PYPR,PZPR,TOTFORR,PXGR,PYGR,PZGR,TOTFORGE,
     9PXPL,PYPL,PZPL,TOTFORL,PXGL,PYGL,PZGL,TOTFORGE,
     1R1XPR,R1YPR,R1ZPR,R2XPR,R2YPR,R2ZPR,
     1R1XPL,R1YPL,R1ZPL,R2XPL,R2YPL,R2ZPL,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1R,P1(2),BDCAP1OR,D1(2),
     4L1(3),H1(3),TOFORP2R,P1(3),BDCAP2OR,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
     7L1(1),H1(1),DCAPR,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     *L1(7),H1(7),DCAPL,D1(7),
     *L1(8),H1(8),TOFORP1L,P1(8),BDCAP1OL,D1(8),
     *L1(9),H1(9),TOFORP2L,P1(9),BDCAP1OL,D1(9),
     9LI(I),DUMB,DUMB)
22    CONTINUE
      CALL CAP(DYN,LI,10,DSB,PSP)
C
C
```

```
C
C       START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C       CAPACITY
C
      ADMIN=AD1(1)
      DO 23 I=2,ISTEP
23         IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
              DELTATO=.1*ADMIN
              DELTATOS=DELTATO/MGS
              DTO=0.0
              DTOS=0.0
                  DO 24 I=1,10
                      DTOS=DTOS+DELTATOS
                      DTO=DTO+DELTATO
                      DYN(I)=DTO
      CALL PLANCA(ISTEP,NCOMP,MGPA,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3DTOS,DTO,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,ALI(I),DUMB,
     4DUMB)
24    CONTINUE
      CALL CAP(DYN,ALI,10,DPLAN,PPLAN)
C
C
C
C       START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C       CAPACITY
C
      BDMIN=BD1(1)
      DO 30 I=2,BISTEP
30         IF(BD1(I).LT.BDMIN)BDMIN=BD1(I)
              DELTATO=.1*BDMIN
              DELTATOS=DELTATO/MGPA
              DTO=0.0
              DTOS=0.0
                  DO 31 I=1,10
                      DTOS=DTOS+DELTATOS
                      DTO=DTO+DELTATO
                      DYN(I)=DTO
      CALL PLANCA(BISTEP,BNCOMP,MGPB,BNS,BNPS,BNPR,BNR,BPHIS1,
     1BPHIR1,BRS,BRPS,BRPR,BRR,BCB,BA,BV,BPB,BN,BEB,BFTT,
     2BB1SM,BPS,BES,BWDSM,BB1RM,BPR,BER,BWDRM,
     3DTOS,DTO,SOPA,SOF,BCS,BLS,BFS,BCR,BLR,BFR,
     4BD1,BL1,BH1,BE1,BLI(I),DUMB,DUMB)
31    CONTINUE
```

```
      CALL CAP(DYN,BLI,10,BDPLAN,BPPLAN)
C
C      START COUNTER FOR LOADS BETWEEEN 15 AND 150 PERCENT OF DYNAMIC
C      CAPACITY
C
      IF(ADMIN.LT.DMIN)DMIN=ADMIN
      IF(BDMIN.LT.DMIN)DMIN=BDMIN
          DELTATO=.1*DMIN
          DELTATOP=DELTATO/MGPA
          DELTATOS=DELTATO/MGS
          DELTATIR=.5*DELTATOS/MG
          DELTATIL=.5*DELTATOS/MG
          DTIR=0.0
          DTIL=0.0
          DTOS=0.0
          DTOPA=0.0
          DTO=0.0
          DO 20 I=1,10
              DTIR=DTIR+DELTATIR
              DTIL=DTIL+DELTATIL
              DTOS=DTOS+DELTATOS
              DTOPA=DTOPA+DELTATOP
              DTO=DTO+DELTATO
              DYN(I)=DTO
C
C     CALCULATE LIFE FOR EACH DYNAMIC CAPACITY
C
      CALL DPBVCA(
     1DTIR,DTIL,DTO,SI,SOF,MG,MGS,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,ZIP,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
     8F,E,PG,E1(1),RPD,RGD,
     9PXPR,PYPR,PZPR,TOTFORR,PXGR,PYGR,PZGR,TOTFORGE,
     9PXPL,PYPL,PZPL,TOTFORL,PXGL,PYGL,PZGL,TOTFORGE,
     1R1XPR,R1YPR,R1ZPR,R2XPR,R2YPR,R2ZPR,
     1R1XPL,R1YPL,R1ZPL,R2XPL,R2YPL,R2ZPL,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L1(2),H1(2),TOFORP1R,P1(2),BDCAP1OR,D1(2),
     4L1(3),H1(3),TOFORP2R,P1(3),BDCAP2OR,D1(3),
     5L1(5),H1(5),TOFORG1,P1(5),BDCAG1O,D1(5),
     6L1(6),H1(6),TOFORG2,P1(6),BDCAG2O,D1(6),
```

```
     7L1(1),H1(1),DCAPR,D1(1),
     8L1(4),H1(4),DCAG,D1(4),
     *L1(7),H1(7),DCAPL,D1(7),
     *L1(8),H1(8),TOFORP1L,P1(8),BDCAP10L,D1(8),
     *L1(9),H1(9),TOFORP2L,P1(9),BDCAP10L,D1(9),
     9LI(I),DUMB,DUMB)
C
C
      CALL PLANCA(ISTEP,NCOMP,MGPA,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
     3DTOS,DTO,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,ALI(I),
     4DUMB,DUMB)
      CALL PLANCA(BISTEP,BNCOMP,MGPB,BNS,BNPS,BNPR,BNR,BPHIS1,
     1BPHIR1,BRS,BRPS,BRPR,BRR,BCB,BA,BV,BPB,BN,BEB,BFTT,
     2BB1SM,BPS,BES,BWDSM,BB1RM,BPR,BER,BWDRM,
     3DTOPA,DTO,SOPA,SOF,BCS,BLS,BFS,BCR,BLR,BFR,BD1,BL1,
     4BH1,BE1,BLI(I),DUMB,DUMB)
      DO 12 IE=1,9
12          ZL1(IE)=L1(IE)
            DO 13 IE=1,ISTEP
13                ZL1(IE+9)=AL1(IE)
                  DO 14 IE=1,BISTEP
14                      ZL1(IE+9+ISTEP)=BL1(IE)
       CALL LIFE(ZL1,INCOMP,ZE1,ZNCOMP,ZLI(I),DUMB)
20    CONTINUE
      CALL CAP(DYN,ZLI,10,DTRANS,PTRANS)
1220  FORMAT('     TOTAL TRANSMISSION'/)
1221  FORMAT('     SPIRAL BEVEL UNIT'/)
1222  FORMAT('     PLANETARY UNIT'/)
      WRITE(1,1221)
      CALL DPLHE(DSB,PSP,LSB,HSB,ESB)
      WRITE(1,1222)
      CALL DPLHE(DPLAN,PPLAN,LPLAN,HPLAN,EPLAN)
      WRITE(1,1222)
      CALL DPLHE(BDPLAN,BPPLAN,BLPLAN,BHPLAN,BEPLAN)
      WRITE(1,1220)
      CALL DPLHE(DTRANS,PTRANS,LTRANS,HTRANS,ETRANS)
      STOP
      END
      SUBROUTINE DPBVCA(
     1TIR,TIL,TOF,SI,SOF,MG,MG1,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,ZIP,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,EGP1,ADJP1,
```

```
     5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, EGP2, ADJP2,
     6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, EGG1, ADJG1,
     7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, EGG2, ADJG2,
     8F, E, PG, EG, RPD, RGD,
     9PXPR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE,
     9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,
     1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
     1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
     2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
     3L1OP1R, H1OP1R, TOFORP1R, PGP1, BDCAP1OR, BDCAP1TR,
     4L1OP2R, H1OP2R, TOFORP2R, PGP2, BDCAP2OR, BDCAP2TR,
     5L1OG1, H1OG1, TOFORG1, PGG1, BDCAG1O, BDCAG1OT,
     6L1OG2, H1OG2, TOFORG2, PGG2, BDCAG2O, BDCAG2OT,
     7LP1OR, HP1OR, DCAPR, DCAPTR,
     8LG1O, HG1O, DCAG, DCAGT,
     7LP1OL, HP1OL, DCAPL, DCAPTL,
     3L1OP1L, H1OP1L, TOFORP1L, PGP1, BDCAP1OL, BDCAP1TL,
     4L1OP2L, H1OP2L, TOFORP2L, PGP2, BDCAP2OL, BDCAP2TL,
     9LSB, HSB, ESB)
      INTEGER PTL, GTL
      REAL LSB, LL(9), EE(9), NCOMP(9)
      REAL L1OP1R, L1OP2R, L1OP1L, L1OP2L, L1OG1, L1OG2, LP1OR, LP1OL, LG1O
      REAL MG, MG1, NP, NG, NBP1, NBP2, NBG1, NBG2
      DATA NCOMP/1., 1., 1., 1., 1., 1., 1., 1., 1./
C----------------------------------------------------------------------
C     CALCULATION OF THE LOADS TRANSMITTED FROM THE LEFT PINION
C----------------------------------------------------------------------
      CALL GPSPR(TIR, AO, F, GAMMA1, ROT, SPR, PHE1, PHSI1, PXPR, PYPR, PZPR)
      TOTFORR=SQRT(PXPR**2+PYPR**2+PZPR**2)
C----------------------------------------------------------------------
C     CALCULATION OF THE LOADS TRANSMITTED FROM THE LEFT PINION
C----------------------------------------------------------------------
      CALL GPSPR(TIL, AO, F, GAMMA1, ROT, SPR, PHE1, PHSI1, PXPL, PYPL, PZPL)
      TOTFORL=SQRT(PXPL**2+PYPL**2+PZPL**2)
C----------------------------------------------------------------------
C     CALCULATION OF THE LOADS TRANSMITTED TO THE GEAR FROM EACH PINION
C----------------------------------------------------------------------
      TOUTR=MG*TIR
      TOUTL=MG*TIL
      ROT1=-ROT
      SPR1=SPR
      CALL GPSPR(TOUTR, AO, F, ZZ1, ROT1, SPR1, PHE1, PHSI1, PXGR, PYGR, PZGR)
      CALL GPSPR(TOUTL, AO, F, ZZ1, ROT1, SPR1, PHE1, PHSI1, PXGL, PYGL, PZGL)
C----------------------------------------------------------------------
C     CHECK CASE FOR BEARING POSITION AND CALCULATE THE LOADS
```

```
C       ON THE BEARINGS TRANSMITTED FROM TH LEFT PINION
C-----------------------------------------------------------------------
        IF(PTL.EQ.2)GO TO 18
        R1XPL=PXPL
        R2XPL=0.0
        GO TO 19
18      R1XPL=0.0
        R2XPL=PXPL
19      CONTINUE
        CALL BLC1(PXPL,PYPL,PZPL,AP,BP,RP,R1YPL,R1ZPL,R2YPL,R2ZPL)
C-----------------------------------------------------------------------
C       CHECK CASE FOR BEARING POSITION AND CALCULATE THE LOADS
C       ON THE BEARINGS TRANSMITTED FROM THE RIGHT PINION
C-----------------------------------------------------------------------
        IF(PTL.EQ.2)GO TO 20
        R1XPR=PXPR
        R2XPR=0.0
        GO TO 21
20      R1XPR=0.0
        R2XPR=PXPR
21      CONTINUE
        CALL BLC1(PXPR,PYPR,PZPR,AP,BP,RP,R1YPR,R1ZPR,R2YPR,R2ZPR)
C-----------------------------------------------------------------------
C       CHECK CASE FOR BEARING POSITION CALCULATE THE LOADS
C       ON THE BEARINGS TRANSMITTED FROM THE GEAR DUE TO THE RIGHT PINION
C-----------------------------------------------------------------------
        IF(GTL.EQ.2)GO TO 22
        R1XGR=PXGR
        R2XGR=0.0
        GO TO 23
22      R1XGR=0.0
        R2XGR=PXGR
23      CONTINUE
        CALL BLC1(PXGR,PYGR,PZGR,AG,BG,RG,R1YGR,R1ZGR,R2YGR,R2ZGR)
C-----------------------------------------------------------------------
C       CHECK CASE FOR BEARING POSITION CALCULATE THE LOADS
C       ON THE BEARINGS TRANSMITTED FROM THE GEAR DUE TO THE PINION
C-----------------------------------------------------------------------
        IF(GTL.EQ.2)GO TO 24
        R1XGL=PXGL
        R2XGL=0.0
        GO TO 25
24      R1XGL=0.0
        R2XGL=PXGL
25      CONTINUE
```

```
      CALL BLC1(PXGL,PYGL,PZGL,AG,BG,RG,R1YGL,R1ZGL,R2YGL,R2ZGL)
C ----------------------------------------------------------------------
C     SUM OF THE TWO RADIAL AND TWO TANGENTIAL FORCES INTO TWO COMPONENTS
C     IN THE RADIAL DIRECTION
C ----------------------------------------------------------------------
      AZIP=(ZIP-90.)*PII/180.
      R1YG=R1YGR-R1YGL*SIN(AZIP)-R1ZGL*COS(AZIP)
      R1ZG=R1ZGR+R1YGL*COS(AZIP)-R1ZGL*SIN(AZIP)
      R2YG=R2YGR-R2YGL*SIN(AZIP)-R2ZGL*COS(AZIP)
      R2ZG=R2ZGR+R2YGL*COS(AZIP)-R2ZGL*SIN(AZIP)
      R1XG=R1XGR+R1XGL
      R2XG=R2XGR+R2XGL
C----------------------------------------------------------------------
C     CALCULATE THE LIFE OF RIGHT PINION BEARING #1
C----------------------------------------------------------------------
      TOFR=TIR*MG*MG1*2.0
      CALL BDCAP(ITYPEP1,R1XPR,R1YPR,R1ZPR,RFP1,NBP1,DP1,ACP1,SOF,ADJP1
     *,BDCAP1,L10P1R,H10P1R,MG,MG1,AK1,TOFORP1R,PGP1,BDCAP10R)
      BDCAP1TR=BDCAP10R*TOFR/TOFORP1R
      LL(2)=L10P1R
      EE(2)=EGP1
C----------------------------------------------------------------------
C     CALCULATE THE LIFE OF RIGHT PINION BEARING #2
C----------------------------------------------------------------------
      CALL BDCAP(ITYPEP2,R2XPR,R2YPR,R2ZPR,RFP2,NBP2,DP2,ACP2,SOF,ADJP2
     *,BDCAP2,L10P2R,H10P2R,MG,MG1,AK2,TOFORP2R,PGP2,BDCAP20R)
      BDCAP2TR=BDCAP20R*TOFR/TOFORP2R
      LL(3)=L10P2R
      EE(3)=EGP2
C----------------------------------------------------------------------
C     CALCULATE THE LIFE OF LEFT PINION BEARING #1
C----------------------------------------------------------------------
      TOFL=TIL*MG*MG1*2.0
      CALL BDCAP(ITYPEP1,R1XPL,R1YPL,R1ZPL,RFP1,NBP1,DP1,ACP1,SOF,ADJP1
     *,BDCAP1,L10P1L,H10P1L,MG,MG1,AK1,TOFORP1L,PGP1,BDCAP10L)
      BDCAP1TL=BDCAP10L*TOFL/TOFORP1L
      LL(8)=L10P1L
      EE(8)=EGP1
C----------------------------------------------------------------------
C     CALCULATE THE LIFE OF LEFT PINION BEARING #2
C----------------------------------------------------------------------
      CALL BDCAP(ITYPEP2,R2XPL,R2YPL,R2ZPL,RFP2,NBP2,DP2,ACP2,SOF,ADJP2
     *,BDCAP2,L10P2L,H10P2L,MG,MG1,AK2,TOFORP2L,PGP2,BDCAP20L)
      BDCAP2TL=BDCAP20L*TOFL/TOFORP2L
      LL(9)=L10P2L
```

```
      EE(9)=EGP2
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF GEAR BEARING #1
C-----------------------------------------------------------------------
      CALL BDCAP(ITYPEG1,R1XG,R1YG,R1ZG,RFG1,NBG1,DG1,ACG1,SOF,ADJG1
     *,BDCAG1,L10G1,H10G1,1.,MG1,AK3,TOFORG1,PGG1,BDCAG10)
      BDCAG10T=BDCAG10*TOF/TOFORG1
      LL(5)=L10G1
      EE(5)=EGG1
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF GEAR BEARING #2
C-----------------------------------------------------------------------
      CALL BDCAP(ITYPEG2,R2XG,R2YG,R2ZG,RFG2,NBG2,DG2,ACG2,SOF,ADJG2
     *,BDCAG2,L10G2,H10G2,1.,MG1,AK4,TOFORG2,PGG2,BDCAG20)
      BDCAG20T=BDCAG20*TOF/TOFORG2
      LL(6)=L10G2
      EE(6)=EGG2
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF THE GEAR
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
      CALL SET1(PHE1,F,E,MG,MG1,NP,NG,SOF,LP10R,HP10R,LP10L,HP10L,
     *LG10,HG10,PG,EG,TOTFORR,TOTFORL,RPD,RGD,DCAPR,DCAPL,DCAG,
     *TOTFORGE)
      DCAPTR=DCAPR*TOFR/TOTFORR
      DCAPTL=DCAPL*TOFL/TOTFORL
      DCAGT=DCAG*TOF/TOTFORGE
      LL(1)=LP10R
      LL(7)=LP10L
      LL(4)=LG10
      EE(1)=EG
      EE(4)=EG
      EE(7)=EG
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF THE TRANSMISSION
C-----------------------------------------------------------------------
      CALL LIFE(LL,9,EE,NCOMP,LSB,ESB)
      HSB=LSB*16666.667/SOF
      RETURN
      END
      FUNCTION BASCAP(R1,R2,PHI,WD,K1)
C-----------------------------------------------------------------------
C FUNCTION SUBROUTINE BASCAP CALCULATES THE BASIC DYNAMIC CAPACITY OF
C A GEAR TOOTH
C-----------------------------------------------------------------------
```

```
      REAL K1,R1,R2,WD,PHI,BASCAP
C
C INPUTS
C
C       K1       MATERIAL CONSTANT OF THE MESH (PSI)
C       R1       PITCH RADIUS OF THE DRIVING GEAR (IN)
C       R2       PITCH RADIUS OF THE DRIVEN GEAR (IN)
C       WD       FACE WIDTH OF THE GEAR MESH (IN)
C       PHI      PRESSURE ANGLE OF THE GEAR MESH (RADIANS)
C
C OUTPUT
C
C       BASCAP   BASIC DYNAMIC CAPACITY OF ONE TOOTH IN THE MESH (LB)
C
      BASCAP=K1*WD*SIN(PHI)/(1.0/R1+1.0/R2)
      RETURN
      END
      SUBROUTINE BDCAP(ITYPE,RX,RY,RZ,V,BALLS,DIA,ANGLE,SPEED2,LAF,
     *BDC,LF,HF,MG,MG1,AK,FE,A,BDCOUT)
C
      REAL LF,L10,MG,MG1,L101,LF1,LAF
C
C -------------------------------------------------------------------
C      THIS SUBROUTINE CALCULATES THE BASIC DYNAMIC CAPACITY AND THE LIFE
C      OF THE BEARING
C
C
C
C -------------------------------------------------------------------
C
C INPUT
C
C      ITYPE -TYPE OF BEARING
C              1 SINGLE ROW BALL BEARING
C              2 DOUBLE ROW BALL BEARING
C              3 SINGLE ROW ROLLER BEARING
C              4 DOUBLE ROW ROLLER BEARING
C              5 SINGLE ROW BALL BEARING + SINGLE ROW ROLLER BEARING
C              6 SINGLE ROW TAPER ROLLER BEARING
C              7 DOUBLE ROW TAPER ROLLER BEARING
C      RX    -AXIAL LOAD ON THE BEARING
C      RY    -RADIAL LOAD ON THE BEARING
C      RZ    -TANGENTIAL LOAD ON THE BEARING
C      V     -ROTATION FACTOR
C      BALLS -NUMBER OF BALLS OR ROLLERS
```

```
C       DIA    -DIAMETER OF BALLS OR ROLLERS
C       ANGLE  -CONTACT ANGLE
C                (ONLY FOR BALL BEARINGS)
C       SPEED2-OUTPUT SPEED OF GEAR SHAFT (RPM)
C       BDC    -BASIC DYNAMIC CAPACITY OF THE BEARING
C       AK     -RATIO OF RADIAL LOAD RATING TO THRUST LOAD RATING
C                (ONLY FOR TAPERED ROLLER BEARINGS)
C       MG     -SPEED RATION FROM OUTPUT SHFT TO COMPONENT
C
C  INPUT
C
C       LF     -LIFE OF THE BEARING (MILLIONS OF CYCLES)
C       HF     -LIFE OF THE BEARING (HOURS)
C       FE     -TOTAL FORCE ON THE BEARING
C
        ARX=ABS(RX)
        A10=SQRT(RY**2+RZ**2)
        IF(ITYPE.GT.1)GOTO20
10      CALL XXYY1(A10,ARX,V,BALLS,DIA,ANGLE,X,Y)
        A=3.0
        GOTO80
20      IF(ITYPE.GT.2)GOTO30
        CALL XXYY2(A10,ARX,V,BALLS,DIA,ANGLE,X,Y)
        A=3.0
        GOTO80
30      IF(ITYPE.GT.4)GOTO60
        X=1.0
        Y=0.0
        A=3.3
        GOTO80
60      IF(ITYPE.GT.5)GOTO70
        CALL TAPER1(A10,ARX,AK,FE)
        A=3.3
        GOTO81
70      CONTINUE
        CALL TAPER2(A10,ARX,AK,FE)
        A=3.3
        GOTO81
80      CONTINUE
        FE=X*V*A10+Y*ARX
81      CONTINUE
        L10=(BDC/FE)**A
        LF=LAF*L10/MG/MG1
        HF=LF*16666.667/SPEED2
        VEG=1./A
```

```
      BDCOUT=(LAF*1./MG/MG1)**VEG*BDC
90    RETURN
      END
      SUBROUTINE BLC1(PX,PY,PZ,A,B,RP,R1Y,R1Z,R2Y,R2Z)
C-----------------------------------------------------------------------
C     THIS SUBROUTINE CALCULATES THE BEARING REACTION FOR CASE #1
C-----------------------------------------------------------------------
C INPUTS
C
C     A   DISTANCE FROM BEARING TO GEAR (IN)
C     B   DISTANCE FROM GEAR TO BEARING (IN)
C     PX  FORCE AXIAL ON THE GEAR (LB)
C     PY  FORCE RADIAL ON THE GEAR (LB)
C     PZ  FORCE TANGENTIAL ON THE GEAR (LB)
C     RP  PITCH RADIUS OF THE GEAR (LB)
C
C OUTPUT
C
C     R1Y REACTION OF BEARING #1 IN THE Y-DIRECTION (LB)
C     R2Y REACTION OF BEARING #2 IN THE Y-DIRECTION (LB)
C     R1Z REACTION OF BEARING #1 IN THE Z-DIRECTION (LB)
C     R1Z REACTION OF BEARING #2 IN THE Z-DIRECTION (LB)
C
      R1Y=(-PY*B+PX*RP)/(A+B)
      R1Z=-PZ*B/(A+B)
      R2Y=(-PY*A-PX*RP)/(A+B)
      R2Z=-PZ*A/(A+B)
      RETURN
      END
C
      SUBROUTINE GPSPR(TI,AO,F,GAMMA,ROT,SPR,PHE,PHSI,PXP,PYP,PZP)
C-----------------------------------------------------------------------
C
C     THIS SUBROUTINE CALCULATES THE LOADS PRODUCED BY THE PINION
C-----------------------------------------------------------------------
C                               INPUTS
C                             ----------
C     TI        INPUT TORQUE (LB-IN)
C     AO        CONE DISTANCE (IN)
C     GAMMA     CONE ANGLE (RADIANS)
C     ROT       DIRECTION OF ROTATION
C               1  FOR CLOCKWISE
C               -1 FOR COUNTERCLOCKWISE
C     SPR       SPIRAL DIRECTION
C               1  RIGHT HAND
```

```
C               -1 LEFT HAND
C      PHE      PRESSURE ANGLE (RADIANS)
C      PHSI     SPIRAL ANGLE (RADIANS)
C
C                              OUTPUT
C                            ----------
C      PXP      THRUST LOAD ON GEAR
C      PYP      RADIAL LOAD ON GEAR
C      PZP      TANGENTIAL LOAD ON GEAR
C-----------------------------------------------------------------------
C      TANGENTIAL TOOTH LOAD
C-----------------------------------------------------------------------
       PZP=-TI/((AO-F/2.0)*SIN(GAMMA))
C-----------------------------------------------------------------------
C     CHECK FOR ROTATION AND HAND OF THE PINION
C-----------------------------------------------------------------------
       ROTSPR=ROT*SPR
       IF(ROTSPR.LT.1.0)GO TO 10
C ----------------------------------------------------------------------
C      THRUST LOAD
C ----------------------------------------------------------------------
       PXP=PZP*(TAN(PHE)*SIN(GAMMA)-SIN(PHSI)*COS(GAMMA))
      */COS(PHSI)
C ----------------------------------------------------------------------
C      RADIAL TOOTH LOAD
C ----------------------------------------------------------------------
       PYP=PZP*(TAN(PHE)*COS(GAMMA)+SIN(PHSI)*SIN(GAMMA))
      */COS(PHSI)
       GO TO 20
10     CONTINUE
C-----------------------------------------------------------------------
C      THRUST LOAD
C-----------------------------------------------------------------------
       PXP=PZP*(TAN(PHE)*SIN(GAMMA)+SIN(PHSI)*COS(GAMMA))
      */COS(PHSI)
C ----------------------------------------------------------------------
C      RADIAL LOAD
C ----------------------------------------------------------------------
       PYP=PZP*(TAN(PHE)*COS(GAMMA)-SIN(PHSI)*SIN(GAMMA))
      */COS(PHSI)
20     RETURN
       END

C
C
```

```
C
C
      SUBROUTINE LEASQR(N,X,Y,A,B)
C
C
C     LEASQR FITS DATA PAIRS WITH A LINEAR EQUATION OF THE FORM
C                  Y=A+BX+E
C           WHERE,         X IS THE INDEPENDENT VARIABLE AND
C                          Y IS THE DEPENDENT VARIABLE.
C                          E IS THE RESIDUAL (WHICH IS MINIMIZED)
C     THE ESTIMATED EQUATION IS THEN Y=A+BX.
C
C
      INTEGER I,N
      REAL A,B,DENOM,NUMA,NUMB,SSX,SXY,SX,SY,X,Y
      DIMENSION X(N),Y(N)
C
C
C THE VARIABLES ARE:
C        N--NUMBER OF DATA PAIRS,(X,Y)(PASSED TO PROGRAM)
C        X--INDEPENDENT VARIABLE OF DATA TO BE FITTED(PASSED TO PROGRAM)
C        Y--DEPENDENT VARIABLE OF DATA TO BE FITTED(PASSED TO PROGRAM)
C        A--Y INTERCEPT OF FITTED LINE(PASSED FROM PROGRAM)
C        B--SLOPE OF THE FITTED LINE(PASSED FROM PROGRAM)
C        I--DO LOOP COUNTER
C        DENOM--INTERMEDIATE CALCULATION
C        NUMA--INTERMEDATE CALCULATION
C        NUMB--INTERMEDATE CALCULATION
C        SSX--SUMMATION OF THE SQUARES OF X
C        SXY--SUMMATION OF THE PRODUCT OF X AND Y
C        SX--SUMMATION OF X
C        SY--SUMMATION OF Y
C
C INITIALIZE SUMMATIONS
C
      SSX=0.0
      SX=0.0
      SXY=0.0
      SY=0.0
C CALCULATE SUMS
C
      DO 10 I=1,N
      SX=SX+X(I)
      SY=SY+Y(I)
      SXY=SXY+X(I)*Y(I)
```

```
      SSX=SSX+X(I)**2
10    CONTINUE
C
C CONVERT N TO REAL TYPE, CALCULATE SLOPE, B AND INTERCEPT, A
C
      NUMA=SY*SSX-SXY*SX
      NUMB=FLOAT(N)*SXY-SX*SY
      DENOM=FLOAT(N)*SSX-SX**2
      A=NUMA/DENOM
      B=NUMB/DENOM
      RETURN
      END
      SUBROUTINE LIFE(ALIFE,NN,EW,NCOMP,LT10,ET)
C-----------------------------------------------------------------------
C
C     LIFE CALCULATES THE WEIBULL EXPONENT FOR THE SPIRAL BEVEL
C     TRANSMISSION AND THE L10 LIFE OF THE TRANSMISSION.
C
C-----------------------------------------------------------------------
      REAL A,E,L,N,S,EB,EG,ET,DIFF,DELTAL,OLDIFF,LT10,NCOMP(NN)
      INTEGER I
      DIMENSION L(25),S(25),ALIFE(NN),EW(NN)
C
C INPUTS
C         NCOMP(I) NUMBER OF EACH COMPONENT
C         EW(I)    WEIBULL EXPONENT OF THE COMPONENT
C         ALIFE(I) L10 LIFE OF CONPONENT
C
C OUTPUT
C
C         ET       WEIBULL EXPONENT OF THE GEAR TRANSMISSION
C         LT10     L10 LIFE OF THE TRANSMISSION IN INPUT
C                  REVOLUTIONS (CYCLES)
C
C MISCELLANEOUS VARIABLES:
C         L(I)     GENERATED SET OF TRANSMISSION LIVES SUN REVS
C         S(I)     SET OF TRANSMISSION RELIABILITIES CORRESPONDING TO
C                  THE SET OF TRANSMISSION LIVES
C         A        INTERCEPT OF LINE CALCULATED BY LEAST SQUARE ROUTINE
C         I        DO LOOP COUNTER
C         E        SMALLER OF THE TWO WEIBULL EXPONENTS
C         DIFF     DIFFERENCE BETWEEN ITERATED PROBABILITY OF SURVIVAL
C                  AND DESIRED VALUE
C         DELTAL   HALF INTERVAL LIFE INCREMENT SUN REVS
C         OLDIFF   PAST VALUE OF DIFF; USED WITH DIFF FOR DETERMINING
```

```
C                 IF ITERATION HAS PASSED DESIRED VALUE
C
C
C CALCULATE THE TRANSMISSION'S L5 LIFE USING A HALF INTERVAL METHOD
C DETERMINE MINIMUM L10 LIFE & CALCULATE SEED VALUE FOR FINDING L5 LIFE
C
      CALL MINIMUM(ALIFE,NN,ASLL)
          L(1)=ASLL/10.
      OLDIFF=1.0
      DELTAL=L(1)
C
C ITERATION FOLLOWS
C
      DO 10 I=1,50
          SLIFE=0.0
          DO 31  IN=1,NN
              SLIFE=SLIFE+NCOMP(IN)*(L(1)/ALIFE(IN))**EW(IN)
31        CONTINUE
          S(1)=0.9**SLIFE
      IF(S(1).GE.0.94.AND.S(1).LE.0.96)GOTO20
      DIFF=S(1)-0.95
      IF(DIFF*OLDIFF.LT.0.0)DELTAL=-DELTAL/2.0
      OLDIFF=DIFF
      L(1)=L(1)+DELTAL
10    CONTINUE
20    CONTINUE
      OLDIFF=1.0
      SL=ASLL/10.
      DELTAL=SL
      DO 11 I=1,50
          SLIFE=0.0
          DO 37 IN=1,NN
              SLIFE=SLIFE+NCOMP(IN)*(SL/ALIFE(IN))**EW(IN)
37        CONTINUE
          SD=SLIFE
      IF(SD.GE.0.99.AND.SD.LE.1.01)GOTO21
      DIFF=SD-1.00
      IF(DIFF*OLDIFF.LT.0.0)DELTAL=-DELTAL/2.0
      OLDIFF=DIFF
      SL=SL-DELTAL
11    CONTINUE
      WRITE(1,100)
100   FORMAT(5X,'ITERATION FOR THE TRANSMISSION''S L5 LIFE WAS',
     1       'UNSUCCESSFUL.'/,5X,'PROGRAM TERMINATING')
C
```

```
C CALCULATE THE TRANSMISSION'S L50 LIFE USING A HALF INTERVAL METHOD
C CALCULATE A SEED VALUE LARGER THE L50 AND ITERATE DOWN TO L50 LIFE
C
21    CONTINUE
      CONTINUE
      E=100.
      DO 34 I=1,NN
      IF(EW(I).LT.E)E=EW(I)
34      CONTINUE
      L(25)=L(1)*(ALOG(1.0/0.5)/ALOG(1.0/0.95))**(1.0/E)
      DELTAL=L(1)
      OLDIFF=1.0
C
C ITERATION FOLLOWS
C
      DO 30 I=1,50
          SLIFE=0.0
          DO 32 IN=1,NN
              SLIFE=SLIFE+NCOMP(IN)*(L(25)/ALIFE(IN))**EW(IN)
32        CONTINUE
          S(25)=0.9**SLIFE
      IF(S(25).GE.0.49.AND.S(25).LE.0.51)GOTO35
      DIFF=0.5-S(25)
      IF(DIFF*OLDIFF.LT.0.0)DELTAL=-DELTAL/2.0
      OLDIFF=DIFF
      L(25)=L(25)-DELTAL
30    CONTINUE
      WRITE(1,110)
110   FORMAT(5X,'ITERATION FOR THE TRANSMISSION''S L50 LIFE WAS',
     1        'UNSUCCESSFUL.'/,5X,'PROGRAM TERMINATING')
      STOP
C
C ITERATIONS FOR L5 AND L50 ARE COMPLETE; CALCULATE LIFE INCREMENT
C FOR GENERATION OF TABLE OF LIVES AND RELIABILITIES (25 DATA PAIRS)
C
35    CONTINUE
      DELTAL=(L(25)-L(1))/24.0
C
C CALCULATE TABLE OF LIVES AND RELIABLITIES (L,S)
C
      DO 40 I=2,24
      L(I)=L(I-1)+DELTAL
          SLIFE=0.0
          DO 33 IN=1,NN
              SLIFE=SLIFE+NCOMP(IN)*(L(I)/ALIFE(IN))**EW(IN)
```

```
33          CONTINUE
            S(I)=0.9**SLIFE
40     CONTINUE
C
C TRANSFORM USING NATURAL LOGS SO A LINEAR REGRESSION MAY BE USED
C
       DO 50 I=1,25
       L(I)=ALOG(L(I))
       S(I)=ALOG(ALOG(1.0/S(I)))
50     CONTINUE
C
C CALCULATE THE TRANSMISSION'S WEIBULL EXPONENT
C
       CALL LEASQR(25,L,S,A,ET)
C
C CALCULATE THE TRANSMISSION'S L10 LIFE
C
       LT10=EXP((ALOG(ALOG(1.0/0.9))-A)/ET)
       RETURN
       END
C
       SUBROUTINE MINIMUM(ALIFE,N,AMIN)
C
C     CHECK FOR MINIMUN NUMBER IN ARRAY
C
       DIMENSION ALIFE(N)
       AMIN=10000000.
       DO 30 I=1,N
            IF(ALIFE(I).LT.AMIN)AMIN=ALIFE(I)
30            CONTINUE
            RETURN
            END
C-----------------------------------------------------------------------
       SUBROUTINE SET1(PHE,F,E,MG,MG1,NP,NG,SPEED2,LP10R,HP10R,
      *LP10L,HP10L,LG10,HG10,PG,EG,FOR,FOL,R1,R2,DCAPR,DCAPL,
      *DCAG,FE)
C-----------------------------------------------------------------------
C      CALCULATION OF THE LIFE OF THE PINION AND GEAR MESH
C-----------------------------------------------------------------------
C
C INPUTS
C
C      PHE   -PRESSURE ANGLE OF THE MESH (RADIANS)
C      F     -FACE WIDTH (IN)
C      E     -MESH MATERIAL CONSTANT (PSI)
```

```
C       MG     -GEAR RATIO
C       NP     -NUMBER OF TEETH OF THE PINION
C       NG     -NUMBER OF TEETH OF THE GEAR
C       SPEED2-SPEED OF OUTPUT SHAFT
C       PG     -MESH MATERIAL CONSTANT
C       EG     -MESH WEIBULL EXPONENT
C       FOR    -TOTAL FORCE TRANSMITTED
C       R1     -REFERENCE PLANE RADIUS OF SPIRAL BEVEL PINION (IN)
C       R2     -REFERENCE PLANE RADIUS OF SPIRAL BEVEL GEAR (IN)
C
C OUTPUT
C
C       LP10   -THE L10 LIFE OF THE PINION (CYCLES)
C       HP10   -THE L10 LIFE OF THE PINION (HOURS)
C       LG10   -THE L10 LIFE OF THE GEAR (CYCLES)
C       HG10   -THE L10 LIFE OF THE GEAR (HOURS)
C       DCAP   -THE DYNAMIC CAPACITY OF THE PINION (LBS)
C       DCAG   -THE DYNAMIC CAPACITY OF THE GEAR (LBS)
C       FOR    -FORCE ON THE PINION
C       FE     -FORCE ON THE GEAR
C
        REAL NP,NG,MG,MG1,LP10R,LP10L,LG10,LP10TR,LP10TL,LG10T
        F1=.5*F
        CBG=BASCAP(R1,R2,PHE,F1,E)
        FE=((FOR**PG+FOL**PG)/2.)**(1./PG)
C
C       CALCULATE LIFE OF GEAR TEETH
C
        LP10TR=(CBG/FOR)**PG
        LP10TL=(CBG/FOL)**PG
        LG10T=(CBG/FE)**PG
        VEG=1./EG
        VPG=1./PG
C
C       CALCULATE LIFE OF PINION AND GEAR
C
        LP10R=(1./NP)**VEG/MG/MG1*LP10TR
        HP10R=LP10R*16666.666/SPEED2
        LP10L=(1./NP)**VEG/MG/MG1*LP10TL
        HP10L=LP10L*16666.666/SPEED2
        LG10=(1./NG)**VEG/MG1*LG10T
        HG10=LG10*16666 666/SPEED2
C
C       CALCULATE BASIC DYNAMIC CAPACITY OF PINION AND GEAR
C
```

```
      DCAPR=((1./NP)**VEG/MG/MG1)**VPG*CBG
      DCAPL=((1./NP)**VEG/MG/MG1)**VPG*CBG
      DCAG=((1./NG)**VEG/MG1)**VPG*CBG
      RETURN
      END
      SUBROUTINE TAPER1(R,T,AK,REA)
C -----------------------------------------------------------------
C     THIS SUROUTINE CALCULATES THE EQUIVALENT REACTION AT A
C     SINGLE ROW TAPERED ROLLER BEARING
C -----------------------------------------------------------------
C INPUT
C     R      -RADIAL LOAD
C     T      -THRUST LOAD
C     AK     -RATIO OF BASIC RADIAL RATING TO BASIC THRUST RATING
C
C OUTPUT
C
C     RE     -EQUIVALENT RADIAL LOAD
C
      REA=.4*R+AK*T
      IF(REA.LT.R)REA=R
      RETURN
      END
      SUBROUTINE TAPER2(R,T,AK,REA)
C -----------------------------------------------------------------
C     THIS SUROUTINE CALCULATES THE EQUIVALENT REACTION AT A
C     DOUBLE ROW TAPERED ROLLER BEARING
C -----------------------------------------------------------------
C INPUT
C     R      -RADIAL LOAD
C     T      -THRUST LOAD
C     AK     -RATIO OF BASIC RADIAL RATING TO BASIC THRUST RATING
C
C OUTPUT
C
C     RE     -EQUIVALENT RADIAL LOAD
C
      CHECK=0.60*R/AK
      IF(T.GT.CHECK)GOTO10
      REA=R*.5+.83*AK*T
      GOTO20
10    REA=0.40*R+AK*T
20    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE XXYY1(FR1,FA,V,BALLS,DIA,ANGLE,X,Y)
C-----------------------------------------------------------------------
C     THIS SUBROUTINE CALCULATES THE RADIAL FACTOR AND THRUST FACTOR
C     FOR SINGLE ROW BALL BEARINGS
C ----------------------------------------------------------------------
C
C INPUTS
C
C     FR1      TOTAL RADIAL LOAD (LBS)
C     FA       TOTAL THRUST LOAD (LBS)
C     V        ROTATION FACTOR OF BEARING
C              1.0 FOR INNER RACE ROTATION
C              1.2 FOR OUTER RACE ROTATION
C     BALLS    NUMBER OF BALLS PER BEARING
C     DIA      DIAMETER OF THE BALLS
C     ANGLE    CONTACT ANGLE OF THE BALL BEARING
C
C OUTPUTS
C     X        RADIAL FACTOR
C     Y        THRUST FACTOR
C
      DIMENSION A(10),Y1(9),Y2(9),Y3(9),E1(9),E2(9),E3(9)
      DATA X1,X2,X3,X4,X5,X6,X7,X8/0.56,0.46,0.44,.43,.41,.39,.37,.35/
      DATA Y4,Y5,Y6,Y7,Y8/1.00,.87,.76,.66, 57/
      DATA E4,E5,E6,E7,E8/0.57,0.68,0.80,0.95,1.14/
      DATA A/25.,50.,100.,150.,200.,300.,500.,750.,1000.,10000./
      DATA Y1/2.30,1.99,1.71,1.55,1.45,1.31,1.15,1.04,1.00/
      DATA Y2/1.88,1.71,1.52,1.41,1.34,1.23,1.10,1.01,1.00/
      DATA Y3/1.47,1.40,1.30,1.23,1.19,1.12,1.02,1.00,1.00/
      ROWS=1.0
      CHECK2=FA/(V*FR1)
      IF(ANGLE.GT.5.00)GOTO10
      CHECK1=FA/(ROWS*BALLS*DIA**2)
      DO 1 I=1,9
          IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO2
1     CONTINUE
      IF(I.GT.9)I=9
2     IF(CHECK2.LE.E1(I))GOTO1000
      X=X1
      Y=Y1(I)
      GOTO999
10    CHECK1=FA/(BALLS*DIA**2)
      IF(ANGLE.GT.10.0)GOTO20
      DO 11 I=1,9
          IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO12
```

```
11      CONTINUE
        IF(I.GT.9)I=9
12      IF(CHECK2.LE.E2(I))GOTO1000
        X=X2
        Y=Y2(I)
        GOTO999
20      IF(ANGLE.GT.15.0)GOTO30
        DO 21 I=1,9
             IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO22
21      CONTINUE
        IF(I.GT.9)I=9
22      IF(CHECK2.LE.E3(I))GOTO1000
        X=X3
        Y=Y3(I)
        GOTO999
30      IF(ANGLE.GT.20.0)GOTO40
        IF(CHECK2.LE.E4)GOTO1000
        X=X4
        Y=Y4
        GOTO999
40      IF(ANGLE.GT.25.0)GOTO50
        IF(CHECK2.LE.E5)GOTO1000
        X=X5
        Y=Y5
        GOTO999
50      IF(ANGLE.GT.30.0)GOTO60
        IF(CHECK2.LE.E6)GOTO1000
        X=X6
        Y=Y6
        GOTO999
60      IF(ANGLE.GT.35.0)GOTO70
        IF(CHECK2.LE.E7)GOTO1000
        X=X7
        Y=Y7
        GOTO999
70      IF(CHECK2.LE.E8)GOTO1000
        X=X8
        Y=Y8
        GOTO999
1000    X=1.0
        Y=0.0
999     RETURN
        END
        SUBROUTINE XXYY2(FR1,FA,V,BALLS,DIA,ANGLE,X,Y)
C----------------------------------------------------------------------
```

```
C      THIS SUBROUTINE CALCULATES THE RADIAL FACTOR AND THRUST FACTOR
C      FOR DOUBLE ROW BALL BEARINGS
C ------------------------------------------------------------------
C
C INPUTS
C
C      FR1      TOTAL RADIAL LOAD (LBS)
C      FA       TOTAL THRUST LOAD (LBS)
C      V        ROTATION FACTOR OF BEARING
C               1.0 FOR INNER RACE ROTATION
C               1.2 FOR OUTER RACE ROTATION
C      BALLS    NUMBER OF BALLS PER BEARING ROW
C      DIA      DIAMETER OF THE BALLS
C      ANGLE    CONTACT ANGLE OF THE BALL BEARING
C
C OUTPUTS
C      X        RADIAL FACTOR
C      Y        THRUST FACTOR
C
      DIMENSION A(10),Y1(9),Y2(9),Y3(9),Y4(9),Y5(9),Y6(9),Y7(9)
      DIMENSION E1(9),E2(9),E3(9),E4(9)
      DATA A/25.,50.,100.,150.,200.,300.,500.,750.,1000.,10000./
      DATA Y1/2.30,1.99,1.71,1.55,1.45,1.31,1.15,1.04,1.00/
      DATA Y2/2.78,2.40,2.07,1.87,1.75,1.58,1.39,1.26,1.21/
      DATA Y3/3.74,3.23,2.78,2.52,2.36,2.13,1.87,1.69,1.63/
      DATA Y4/2.18,1.98,1.76,1.63,1.55,1.42,1.27,1.17,1.16/
      DATA Y5/3.06,2.78,2.47,2.29,2.18,2.00,1.79,1.64,1.63/
      DATA Y6/1.65,1.57,1.46,1.38,1.34,1.26,1.14,1.12,1.12/
      DATA Y7/2.39,2.28,2.11,2.00,1.93,1.82,1.66,1.63,1.63/
      DATA E1/0.19,0.22,0.26,0.28,0.30,0.34,0.38,0.42,0.44/
      DATA E2/0.23,0.26,0.30,0.34,0.36,0.40,0.45,0.50,0.52/
      DATA E3/0.29,0.32,0.36,0.38,0.40,0.44,0.49,0.54,0.54/
      DATA E4/0.38,0.40,0.43,0.46,0.47,0.50,0.55,0.56,0.56/
      DATA X1,X2,X3,X4,X5,X6,X7,X8/0.56,1.,0.78,1.,0.75,1.,0.72,1./
      DATA X9,X10,X11,X12,X13,X14,X15,X16,X17/0.70,1.,0.67,1.,0.63
     *,1.,0.60,1.,0.93/
      DATA Y8,Y9,Y10,Y11,Y12,Y13,Y14,Y15,Y16,Y17/1.09,1.63,0.92,1.41,
     *0.78,1.24,0.66,1.07,0.55,0.93/
      DATA E5,E6,E7,E8,E9/0.57,0.68,0.80,0.95,1.14/
      ROWS=2.0
      CHECK2=FA/(V*FR1)
      IF(ANGLE.GT.5.0)GOTO10
      CHECK1=FA/(ROWS*BALLS*DIA**2)
      DO 1 I=1,9
          IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO2
```

```
1       CONTINUE
        IF(I.GT.9)I=9
2       IF(CHECK2.LE.E1(I))GOTO3
        X=X1
        Y=Y1(I)
        GOTO999
3       X=1.0
        Y=0.0
        GOTO999
10      CHECK1=FA/(BALLS*DIA**2)
        IF(ANGLE.GT.10.0)GOTO20
        DO 11 I=1,9
            IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO12
11      CONTINUE
        IF(I.GT.9)I=9
12      IF(CHECK2.LE.E2(I))GOTO13
        X=X3
        Y=Y3(I)
        GOTO999
13      X=X2
        Y=Y2(I)
        GOTO999
20      IF(ANGLE.GT.10.)GOTO30
        DO 21 I=1,9
            IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO22
21      CONTINUE
        IF(I.GT.9)I=9
22      IF(CHECK1.LE.E3(I))GOTO23
        X=X5
        Y=Y5(I)
        GOTO999
23      X=X4
        Y=Y4(I)
        GOTO999
30      IF(ANGLE.GT.15.)GOTO40
        DO 31 I=1,9
            IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO32
31      CONTINUE
        IF(I.GT.9)I=9
32      IF(CHECK2.LE.E4(I))GOTO33
        X=X7
        Y=Y7(I)
        GOTO999
33      X=X6
        Y=Y6(I)
```

```
      GOTO999
40    IF(ANGLE.GT.20.)GOTO50
      IF(CHECK2.LE.E5)GOTO43
      X=X9
      Y=Y9
      GOTO999
43    X=X8
      Y=Y8
      GOTO999
50    IF(ANGLE.GT.25.0)GOTO60
      IF(CHECK2.LE.E6)GOTO53
      X=X11
      Y=Y11
      GOTO999
53    X=X10
      Y=Y10
      GOTO999
60    IF(ANGLE.GT.30.0)GOTO70
      IF(CHECK2.LE.E7)GOTO63
      X=X13
      Y=Y13
      GOTO999
63    X=X12
      Y=Y12
      GOTO999
70    IF(ANGLE.GT.35.0)GOTO80
      IF(CHECK2.LE.E8)GOTO73
      X=X15
      Y=Y15
      GOTO999
73    X=X14
      Y=Y14
      GOTO999
80    IF(CHECK2.LE.E9)GOTO83
      X=X17
      Y=Y17
      GOTO999
83    X=X16
      Y=Y16
999   RETURN
      END
      SUBROUTINE DPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,EG,PG,
     1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
     2BDCAP1,RFP1,EGP1,ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,EGP2,
     3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,EGG1,
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     4ITYPEG2, NBG2, DG2, ACG2, AK4, BDCAG2, RFG2, EGG2, MG, GAMMA1, GAMMA, ZZ,
     5ZZ1, DP, DG, RPD, RP, RGD, RG, HK, AOG, AOP, HT, BOG, BOP, PD,
     6ADJP1, ADJP2, ADJG1, ADJG2, ZIP)
C
C     SPIRAL BEVEL INPUT
C
      CHARACTER*9 DATAFILE
      INTEGER NO, YES, ANSWER, CASEP, CASEG, PTL, GTL
      REAL NP, NG, MG, NBP1, NBP2, NBG1, NBG2
      PARAMETER(NO='NO', YES='YES')
      PII=3.141592654
      WRITE(1,300)
300   FORMAT(///' DUAL PINION SPIRAL BEVEL GEAR UNIT INPUTS'///)
      WRITE(1,999)
      READ(1,99)ANSWER
      IF(ANSWER.EQ.NO)GO TO 501
      WRITE(1,502)
502   FORMAT('WHAT IS THE NAME OF THE INPUT FILE')
      READ(1,503)DATAFILE
503   FORMAT(A)
      OPEN(UNIT=55,FILE=DATAFILE,STATUS='UNKNOWN')
      NRE=55
      GO TO 500
501   NRE=1
500   CONTINUE
      CALL GEARINP(NRE,NP,NG,AO,PHE,F,PHSI,ROT,SPR,
     *THETA,E,EG,PG)
      CALL GEAROUT(NP,NG,AO,PHE,F,PHSI,ROT,SPR,
     *THETA,E,EG,PG)
      WRITE(1,1070)
      READ(NRE,*)LL1
      IF(LL1.EQ.1)GOTO500
      WRITE(1,5000)
      READ(NRE,*)ZIP
      PHE1=PHE*PII/180.
      PHSI1=PHSI*PII/180.
      TI=TI*ROT
      THETA1=THETA*PII/180.
C
C
C ENTERING THE VALUES FOR THE PINION AND ITS BEARINGS
C
C
      WRITE(1,1074)
600   CONTINUE
```

```
      CALL CASEINP(NRE,CASEP,PTL,AP,BP)
      CALL CASEOUT(CASEP,PTL,AP,BP)
      WRITE(1,1070)
      READ(NRE,*)L1
      IF(L1.EQ.1)GOTO600
601   CONTINUE
      WRITE(1,1040)
      CALL BEARINP(NRE,ITYPEP1,NBP1,DP1,ACP1,AK1,BDCAP1,RFP1,EGP1,ADJP1)
      CALL BEAROUT(ITYPEP1,NBP1,DP1,ACP1,AK1,BDCAP1,RFP1,EGP1,ADJP1)
      WRITE(1,1070)
      READ(NRE,*)L2
      IF(L2.EQ.1)GOTO601
602   CONTINUE
      WRITE(1,1045)
      CALL BEARINP(NRE,ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,EGP2,ADJP2)
      CALL BEAROUT(ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,EGP2,ADJP2)
      WRITE(1,1070)
      READ(NRE,*)L3
      IF(L3.EQ.1)GOTO602
C
C
C     INPUT THE GEAR AND ITS SUPPORTING BEARINGS
C
C
      WRITE(1,1075)
603   CONTINUE
      CALL CASEINP(NRE,CASEG,GTL,AG,BG)
      CALL CASEOUT(CASEG,GTL,AG,BG)
      WRITE(1,1070)
      READ(NRE,*)L4
      IF(L4.EQ.1)GOTO603
604   CONTINUE
      WRITE(1,1040)
      CALL BEARINP(NRE,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,EGG1,ADJG1)
      CALL BEAROUT(ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,EGG1,ADJG1)
      WRITE(1,1070)
      READ(NRE,*)L5
      IF(L5.EQ.1)GOTO604
605   CONTINUE
      WRITE(1,1045)
      CALL BEARINP(NRE,ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,EGG2,ADJG2)
      CALL BEAROUT(ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,EGG2,ADJG2)
      WRITE(1,1070)
      READ(NRE,*)L6
      IF(L6.EQ.1)GOTO605
```

```
      CLOSE(55)
C-----------------------------------------------------------------------
C     CALCULATION OF GEAR RATIO AND OUTPUT SPEED
C-----------------------------------------------------------------------
      MG=NG/NP
      SPEED2=SPEED/MG
C-----------------------------------------------------------------------
C     CALCULATION OF GAMMA
C-----------------------------------------------------------------------
      GAMMA1=ATAN(SIN(THETA1)/(MG+COS(THETA1)))
      GAMMA=GAMMA1*180./PII
      ZZ=THETA-GAMMA
      ZZ1=ZZ*PII/180.
C-----------------------------------------------------------------------
C     CALCULATION OF PITCH DIAMETER OF GEAR AND PINION
C     AND REFERENCE PITCH DIAMETER OF GEAR AND PINION
C-----------------------------------------------------------------------
      DP=(AO-F/2.)*(2.*SIN(GAMMA1))
      DG=(AO-F/2.)*(2.*SIN(ZZ1))
      PD=NG/DG
      RPD=DP*.5/COS(GAMMA1)
      RP=DP*.5
      RGD=DG*.5/COS(ZZ1)
      RG=DG*.5
C-----------------------------------------------------------------------
C     WORKING DEPTH
C-----------------------------------------------------------------------
      HK=1.70/PD
C-----------------------------------------------------------------------
C     ADDENDUM OF GEAR AND PINION
C-----------------------------------------------------------------------
      AOG=0.46/PD+0.390/(PD*MG**2)
      AOP=HK-AOG
C-----------------------------------------------------------------------
C     WHOLE DEPTH
C-----------------------------------------------------------------------
      IF(PD.LT.10.)GO TO 50
      HT=1.888/PD
      GOTO51
50    HT=1.888/PD+.005
51    CONTINUE
C-----------------------------------------------------------------------
C     DEDENDUM OF THE GEAR AND PINION
C-----------------------------------------------------------------------
      BOG=HT-AOG
```

```
      BOP=HT-AOP
C-----------------------------------------------------------------------
      BOP=HT-AO
999   FORMAT('DO YOU WISH TO USE A DATA SET'/
     *'ANSWER YES OR NO')
1040  FORMAT('PINION BEARING #1')
1045  FORMAT('PINION BEARING #2')
1046  FORMAT('GEAR BEARING #1')
1047  FORMAT('GEAR BEARING #2')
1070  FORMAT('DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS'/
     *'ENTER 1 TO CHANGE')
1074  FORMAT('PINION MOUNTING')
1075  FORMAT('GEAR MOUNTING')
5000  FORMAT('WHAT IS THE ANGLE BETWEEN THE TWO PINIONS')
99    FORMAT(1A4)
      RETURN
      END
      SUBROUTINE CASEINP(NRE,CS,TL,A,B)
      INTEGER CS,TL
C -----------------------------------------------------------------------
C     INPUT FOR CASE OF BEARING AND GEAR MOUNTING
C -----------------------------------------------------------------------
C
      WRITE(1,1017)
      READ(NRE,*)CS
      WRITE(1,1048)
      READ(NRE,*)TL
      WRITE(1,1018)
      READ(NRE,*)A
      WRITE(1,1019)
      READ(NRE,*)B
      IF(CS.EQ.2)A=-A
1017  FORMAT('WHICH CASE OF BEARING PLACEMENT IS BEING USED'/
     *'CASE # 1'/
     *'BEARING--------GEAR-----------BEARING'/
     *'  #1                          #2'/
     *'*-------A---------*-------B--------*'//
     *'CASE # 2'/
     *'GEAR----------BEARING---------BEARING'/
     *'                 #1                #2'/
     *'*-------A---------*'/
     *'*---------------B---------------*')
1048  FORMAT('WHICH BEARING CARRIES THE THRUST LOAD'/
     *'BEARING #1 OR BEARING #2')
1018  FORMAT('ENTER DISTANCE A - DISTANCE FROM * TO * (IN)')
```

```
1019  FORMAT('ENTER DISTNACE B - DISTANCE FROM * TO * (IN)')
100   FORMAT(F15.5)
12    FORMAT(I1)
      RETURN
      END
      SUBROUTINE CASEOUT(CS,TL,A,B)
      INTEGER CS,TL
C ----
C     CASE ECHO
C -----
      WRITE(1,100)CS,TL,A,B
100   FORMAT(/
     *'CASE NUMBER                              ',I3/
     *'BEARING TAKING THE THRUST LOAD           ',I3/
     *'DISTANCE A                               ',F14.4/
     *'DISTANCE B                               ',F14.4/)
      RETURN
      END
      SUBROUTINE BEARINP(NRE,ITYPE,NB,D,AC,AK,BDCAP,RF,EQ,ADJ)
C -----
C     BEARING INPUT
C -----
      REAL NB
      WRITE(1,1000)
      READ(NRE,*)ITYPE
      IF(ITYPE.EQ.3.OR.ITYPE.EQ.4)GOTO410
      IF(ITYPE.GT.4)GOTO400
      WRITE(1,1001)
      READ(NRE,*)NB
      WRITE(1,1002)
      READ(NRE,*)D
      WRITE(1,1003)
      READ(NRE,*)AC
      GOTO410
400   CONTINUE
      IF(ITYPE.LE.5)GOTO410
      WRITE(1,1004)
      READ(NRE,*)AK
410   CONTINUE
      WRITE(1,1005)
      READ(NRE,*)BDCAP
      IF(ITYPE.GT.4)GOTO420
      WRITE(1,1007)
      READ(NRE,*)RF
420   CONTINUE
```

```
      WRITE(1,1008)
      READ(NRE,*)EG
      WRITE(1,1010)
      READ(NRE,*)ADJ
1000  FORMAT('TYPE OF BEARING - ENTER NUMBER'/
     *'  1 - SINGLE ROW BALL BEARING'/
     *'  2 - DOUBLE ROW BALL BEARING'/
     *'  3 - SINGLE ROW ROLLER BEARING'/
     *'  4 - DOUBLE ROW ROLLER BEARING'/
     *'  5 - SINGLE ROW TAPERED ROLLER BEARING'/
     *'  6 - DOUBLE ROW TAPERED ROLLER BEARING')
1001  FORMAT('NUMBER OF BALLS OR ROLLERS')
1002  FORMAT('DIAMETER OF BALLS  OR ROLLERS')
1003  FORMAT('BEARING CONTACT ANGLE')
1004  FORMAT('WHAT IS THE RATIO OF BASIC RADIAL RATING TO'/
     *'BASIC THRUST RATING FOR TAPERED ROLLER BEARINGS')
1005  FORMAT('ENTER THE BASIC DYNAMIC CAPACITY OF BEARING')
1007  FORMAT('ENTER THE ROTATION FACTOR'/
     *'1.0 FOR INNER RACE ROTATION'/
     *'1.2 FOR OUTER RACE ROTATION')
1008  FORMAT('WHAT IS THE WEIBULL EXPONENT FOR THE BEARING')
1010  FORMAT('WHAT IS THE LIFE ADJUSTMENT FACTOR')
100   FORMAT(F15.5)
12    FORMAT(I1)
      RETURN
      END
      SUBROUTINE BEAROUT(ITYPE,NB,D,AC,AK,BDCAP,RF,EG,ADJ)
C ----
C     BEARING ECHO
C ----
      REAL NB
      WRITE(1,100)ITYPE,NB,D,AC,AK,BDCAP,RF,EG,ADJ
100   FORMAT(/
     *' TYPE OF BEARING________________________________    ',I3/
     *' NUMBER OF ROLLING ELEMENTS_____________________    ',F14.5/
     *' DIAMETER OF ROLLING ELEMENTS___________________    ',F14.5/
     *' CONTACT ANGLE (BALL BEARING ONLY)______________    ',F14.5/
     *' RADIAL TO THRUST RATIO'/
     *' (TAPER ROLLER BEARING ONLY)____________________    ',F14.5/
     *' BASIC DYNAMIC CAPACITY_________________________    ',F14.5/
     *' ROTATION FACTOR________________________________    ',F14.5/
     *' WEIBULL EXPONENT_______________________________    ',F14.5/
     *' LIFE ADJUSTMENT FACTOR_________________________    ',F14.5/)
      RETURN
      END
```

```
      SUBROUTINE GEARINP(NRE,NP,NG,AO,PHE,F,PHSI,ROT,SPR,
     *THETA,E,EG,PG)
      REAL NP,NG
      WRITE(1,1050)
      READ(NRE,*)NP
      WRITE(1,1051)
      READ(NRE,*)NG
      WRITE(1,1052)
      READ(NRE,*)AO
      WRITE(1,1053)
      READ(NRE,*)PHE
      WRITE(1,1054)
      READ(NRE,*)F
      WRITE(1,1058)
      READ(NRE,*)PHSI
      WRITE(1,1059)
      READ(NRE,*)ROT
      WRITE(1,1060)
      READ(NRE,*)SPR
      WRITE(1,1061)
      READ(NRE,*)THETA
      WRITE(1,1063)
      READ(NRE,*)E
      WRITE(1,1064)
      READ(NRE,*)EG
      WRITE(1,1065)
      READ(NRE,*)PG
 1050 FORMAT('WHAT IS THE NUMBER OF TEETH ON THE PINION')
 1051 FORMAT('WHAT IS THE NUMBER OF TEETH OF THE GEAR')
 1052 FORMAT('WHAT IS THE CONE DISTANCE OF THE GEAR MESH')
 1053 FORMAT('WHAT IS THE NORMAL PRESURE ANGLE (DEG)')
 1054 FORMAT('WHAT IS THE FACE WIDTH OF THE GEAR MESH (IN)')
 1058 FORMAT('WHAT IS THE SPIRAL ANGLE OF THE PINION')
 1059 FORMAT('WHAT IS THE DIRECTION OF PINION ROTATION'/
     *'LOOKING FROM THE APEX TO THE FACE OF THE PINION'/
     *'(COUNTERCLOCKWISE INPUT 1)'/
     *'(CLOCKWISE INPUT -1 )')
 1060 FORMAT('WHAT IS THE HAND OF THE SPIRAL ANGLE ON THE PINION'/
     *'(RIGHT INPUT 1)'/
     *'(LEFT INPUT -1)')
 1061 FORMAT('WHAT IS THE SHAFT ANGLE BETWEEN THE CENTER LINE OF THE'/
     *'PINION SHAFT AND THE CENTER LINE OF THE GEAR SHAFT (DEG)')
 1063 FORMAT('WHAT IS THE MESH MATERIAL CONSTANT (PSI)')
 1064 FORMAT('WHAT IS THE MESH WEIBULL EXPONENT')
 1065 FORMAT('WHAT IS THE MESH LOAD-LIFE FACTOR')
```

```
      RETURN
      END
      SUBROUTINE GEAROUT(NP,NG,AO,PHE,F,PHSI,ROT,SPR,
     *THETA,E,EG,PG)
      REAL NP,NG
      WRITE(1,1071)NP,NG,AO,PHE,F,PHSI
     *,ROT,SPR,THETA,E,EG,PG
 1071 FORMAT(/
     *' NUMBER OF TEETH ON PINION                         ',F14.3/
     *' NUMBER OF TEETH ON GEAR                           ',F14.3/
     *' CONE DISTANCE                                     ',F14.5/
     *' NORMAL PRESSURE ANGLE                             ',F14.5/
     *' FACE WIDTH                                        ',F14.5/
     *' SPIRAL ANGLE                                      ',F14.5/
     *' DIRECTION OF ROTATION                             ',F14.5/
     *' HAND OF SPIRAL                                    ',F14.5/
     *' SHAFT ANGLE BETWEEN PINION AND GEAR               ',F14.5/
     *' GEAR MESH MATERIAL CONSTANT                       ',F14.5/
     *' WEIBULL EXPONENT                                  ',F14.5/
     *' MESH LOAD LIFE FACTOR                             ',F14.5/)
      RETURN
      END
      SUBROUTINE CAP(T,TL10,N,DYCAPT,PGT)
C
C     T      SET OF TORQUES
C     TL10   SET OF  TRANSMISSION  LIVES AT TORQUE
C     N      NUMBER OF DATA SETS
C
C     DYCAPT DYNAMIC CAPACITY OF THE TRANSMISSION
C     PGT    LOAD LIFE EXPONENT FOR THE TRANSMISSION
C
      DIMENSION T(N),TL10(N),ALT(100),ALTL10(100)
      DO 20 I=1,N
          ALT(I)=ALOG(T(I))
          ALTL10(I)=ALOG(TL10(I))
 20   CONTINUE
      CALL LEASQR(N,ALTL10,ALT,TINT,SLOPE)
      DYCAPT=EXP(TINT)
      PGT=-1./SLOPE
      RETURN
      END
      SUBROUTINE DPBVOT(PD,PHE,PHSI,SPR,F,AO,SI,SOF,ROT,TIR,TIL,TOF,
     1THETA,NP,GAMMA,DP,RPD,AOP,BOP,
     2PXPR,PYPR,PZPR,TOTFORR,DCAPR,CASEP,AP,BP,
     3R1XPR,R1YPR,R1ZPR,TOFORP1R,BDCAP1OR,
```

```
     4R2XPR, R2YPR, R2ZPR, TOFORP2R, BDCAP2OR,
     2PXPL, PYPL, PZPL, TOTFORL, DCAPL, CASEP, AP, BP,
     3R1XPL, R1YPL, R1ZPL, TOFORP1L, BDCAP1OL,
     4R2XPL, R2YPL, R2ZPL, TOFORP2L, BDCAP2OL,
     5NG, ZZ, DG, RGD, AOG, BOG,
     6PXGR, PYGR, PZGR, TOTFORGE, DCAG, CASEG, AG, BG,
     6PXGL, PYGL, PZGL, TOTFORGE, DCAG, CASEG, AG, BG,
     7R1XG, R1YG, R1ZG, TOFORG1, BDCAG1O,
     8R2XG, R2YG, R2ZG, TOFORG2, BDCAG2O,
     9D1, P1, L1, H1, E1)
C -----------------------------------------------------------------
C      PRINT OUT RESULTS
C -----------------------------------------------------------------
      REAL NP, NG, D1(9), P1(9), L1(9), H1(9), E1(9)
      INTEGER CASEP, CASEG
      WRITE(1, 1000)
1000  FORMAT(///
     1'          SPIRAL BEVEL GEAR UNIT'///)
      WRITE(1, 1200)PD, PHE, PHSI, SPR, F, AO, SI, SOF
     *, ROT, TIR, TIL, TOF, THETA
      WRITE(1, 1208)
      WRITE(1, 1202)NP, GAMMA, DP, RPD, AOP, BOP, PXPR, PYPR, PZPR
     *, TOTFORR, DCAPR
      WRITE(1, 1205)CASEP, AP, BP, R1XPR, R1YPR, R1ZPR
     *, TOFORP1R, BDCAP1OR, R2XPR, R2YPR, R2ZPR, TOFORP2R, BDCAP2OR
      WRITE(1, 1209)
      WRITE(1, 1202)NP, GAMMA, DP, RPD, AOP, BOP, PXPL, PYPL, PZPL
     *, TOTFORL, DCAPL
      WRITE(1, 1205)CASEP, AP, BP, R1XPL, R1YPL, R1ZPL
     *, TOFORP1L, BDCAP1OL, R2XPL, R2YPL, R2ZPL, TOFORP2L, BDCAP2OL
      WRITE(1, 1210)
      WRITE(1, 1202)NG, ZZ, DG, RGD, AOG, BOG, PXGR, PYGR, PZGR,
     *TOTFORGE, DCAG
      WRITE(1, 1230)
      WRITE(1, 1202)NG, ZZ, DG, RGD, AOG, BOG, PXGL, PYGL, PZGL,
     *TOTFORGE, DCAG
      WRITE(1, 1205)CASEG, AG, BG, R1XG, R1YG, R1ZG
     *, TOFORG1, BDCAG1O, R2XG, R2YG, R2ZG, TOFORG2, BDCAG2O
1200  FORMAT(//'    GEAR MESH CHARACTERISTICS              '//
     *' PITCH                                       ', F8.2/
     *' NORMAL PRESSURE ANGLE                       ', F8.2/
     *' SPIRAL ANGLE                                ', F8.2/
     *' HAND OF THE SPIRAL OF THE PINION GEAR       ', F8.3/
     *' FACE WIDTH                                  ', F8.3, ' IN'/
     *' CONE DISTANCE                               ', F8.3, ' IN'/
```

```
     *' INPUT SPEED OF THE PINION SHAFT              ',F10.2,' RPM'/
     *' OUTPUT SPEED OF GEAR SHAFT                   ',F10.2,' RPM'/
     *' DIRECTION OF INPUT SHAFT ROTATION            ',F8.3/
     *' INPUT TORQUE OF THE RIGHT PINION SHAFT       ',F10.2,' IN-LB'/
     *' INPUT TORQUE OF THE LEFT PINION SHAFT        ',F10.2,' IN-LB'/
     *' OUTPUT TORQUE OF THE GEAR SHAFT              ',F10.2,' IN-LB'/
     *' ANGLE BETWEEN INPUT AND OUTPUT SHAFT         ',F8.2,' DEG'/)
1202  FORMAT(
     *' NUMBER OF TEETH                              ',F8.2/
     *' PITCH ANGLE                                  ',F8.2,' DEG'/
     *' PITCH DIAMETER                               ',F8.2,' IN'/
     *' REFERENCE PITCH DIAMETER                     ',F8.3,' IN'/
     *' ADDENDUM                                     ',F8.3,' IN'/
     *' DEDENDUM                                     ',F8.3,' IN'/
     *'    FORCES ON A TOOTH IN THE MESH'//
     *' AXIAL FORCE                                  ',F9.1,' LB'/
     *' RADIAL FORCE                                 ',F9.1,' LB'/
     *' TANGENTIAL FORCE                             ',F9.1,' LB'/
     *' TOTAL FORCE                                  ',F9.1,' LB'/
     *' DYNAMIC CAPACITY IN FORCE                    ',F9.1,' LB'/)
1205  FORMAT( '      MOUNTING CHARACTERISTICS'//
     *' TYPE OF MOUNTING                             ',I5/
     *' DISTANCE A                                   ',F8.3/
     *' DISTANCE B                                   ',F8.3//
     *' AXIAL LOAD                                   ',F10.2,' LBS'/
     *' RADIAL LOAD                                  ',F10.2,' LBS'/
     *' TANGENTIAL LOAD                              ',F10.2,' LBS'/
     *' TOTAL EQUIVALENT FORCE                       ',F10.2,' LBS'/
     *' BASIC DYNAMIC CAPACITY OF BEARING #1         ',F10.1,' LBS'//
     *' AXIAL LOAD                                   ',F10.2,' LBS'/
     *' RADIAL LOAD                                  ',F10.2,' LBS'/
     *' TANGENTIAL LOAD                              ',F10.2,' LBS'/
     *' TOTAL EQUIVALENT FORCE                       ',F10.2,' LBS'/
     *' BASIC DYNAMIC CAPACITY OF BEARING #2         ',F10.1,' LBS'//)
1208  FORMAT(///'  RIGHT PINION CHARACTERISTICS AND MOUNTING      '//)
1209  FORMAT(///'  LEFT PINION CHARACTERISTICS AND MOUNTING      '//)
1210  FORMAT(//
     *'  GEAR CHARACTERISTICS AND MOUNTING-MESH WITH RIGHT PINION'//)
1230  FORMAT(//
     *'  GEAR CHARACTERISTICS AND MOUNTING-MESH WITH LEFT PINION'//)
      WRITE(1,1220)
      WRITE(1,1211)
      CALL DPLHE(D1(1),P1(1),L1(1),H1(1),E1(1))
      WRITE(1,1213)
      CALL DPLHE(D1(2),P1(7),L1(2),H1(2),E1(2))
```

```
      WRITE(1,1214)
      CALL DPLHE(D1(3),P1(8),L1(3),H1(3),E1(3))
      WRITE(1,1212)
      CALL DPLHE(D1(7),P1(7),L1(7),H1(7),E1(7))
      WRITE(1,1215)
      CALL DPLHE(D1(8),P1(8),L1(8),H1(8),E1(8))
      WRITE(1,1216)
      CALL DPLHE(D1(9),P1(9),L1(9),H1(9),E1(9))
      WRITE(1,1217)
      CALL DPLHE(D1(4),P1(4),L1(4),H1(4),E1(4))
      WRITE(1,1218)
      CALL DPLHE(D1(5),P1(5),L1(5),H1(5),E1(5)
      WRITE(1,1219)
      CALL DPLHE(D1(6),P1(6),L1(6),H1(6),E1(6))
 1220 FORMAT(////
     *'          DYNAMIC CAPACITY AND LIFE IN TERMS OF'/
     *'                 OUTPUT TORQUE AND SPEED'///)
 1211 FORMAT(' RIGHT INPUT PINION'/)
 1213 FORMAT(' RIGHT INPUT BEARING #1'/)
 1214 FORMAT(' RIGHT INPUT BEARING #2'/)
 1212 FORMAT(' LEFT INPUT PINION'/)
 1215 FORMAT(' LEFT INPUT BEARING #1'/)
 1216 FORMAT(' LEFT INPUT BEARING #2'/)
 1217 FORMAT(' OUTPUT GEAR'/)
 1218 FORMAT(' OUTPUT BEARING #1'/)
 1219 FORMAT(' OUTPUT BEARING #2'/)
      RETURN
      END
      SUBROUTINE DPLHE(DCAP,PG,LIFE,HOUR,EG)
      REAL DCAP,PG,LIFE,HOUR,EG
C
C
C
      WRITE(1,1221)DCAP,PG,LIFE,HOUR,EG
 1221 FORMAT(
     *'        DYNAMIC CAPACITY                          ',F14.4,' LB-IN '/
     *'        LOAD LIFE EXPONENT                        ',F14.4/
     *'        LIFE IN MILLION OUTPUT ROTATIONS          ',F14.4/
     *'        LIFE IN HOURS                             ',F14.4/
     *'        WEIBULL EXPONENT                          ',F14.4/)
      RETURN
      END
      SUBROUTINE PLANCA(ISTEP,NCOMP,MG1,NS,NPS,NPR,NR,PHIS1,PHIR1,
     1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
     2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
```

```
     3TI, TOF, SI, SOF, CS, LS, FS, CR, LR, FR, D1, L10, H1, E1,
     4LPLAN, HPLAN, EPLAN)
C
C
C
      REAL NS, NPS, NPR, NR, N, LS, LR, LS10, LPS10, LPR10, LP10, LB10, LPLAN
      REAL NCOMP(5), L10(5), E1(5), D1(5), H1(5), LR10
C
C
C
      CALL BEAR(MG1, CB, A, V, PB, PHIR1, PHIS1, RR, RS, RPR, RPS, N, FTT,
     1          TI, TOF, SI, SOF, DB, LB10, HB10)
      L10(1)=LB10
      H1(1)=HB10
      E1(1)=EB
      D1(1)=DB
      CALL SUN(MG1, NS, PHIS1, B1SM, PS, ES, RR, RS, RPR, RPS, N, WDSM,
     1          TI, TOF, SI, SOF, CS, LS, FS, DS, LS10, HS10)
      L10(2)=LS10
      H1(2)=HS10
      E1(2)=ES
      D1(2)=DS
      CALL RING(MG1, NR, PHIR1, B1RM, PR, ER, RR, RS, RPR, RPS, N, WDRM,
     1           TI, TOF, SI, SOF, CR, LR, FR, DR, LR10, HR10)
      L10(3)=LR10
      H1(3)=HR10
      E1(3)=ER
      D1(3)=DR
      IF(ISTEP.EQ.5)GOTO25
      CALL PLANET1(MG1, ES, PS, ER, PR, RS, RR, RPS, RPR, TI, TOF, SI, SOF,
     *              N, NPR, LS, FS, LR, FR, LP10, DP, HP10)
      E1(4)=ES
      L10(4)=LP10
      H1(4)=HP10
      D1(4)=DP
      GO TO 26
25    CONTINUE
      CALL PLANET2(MG1, NPS, LS, FS, PS, ES, RR, RS, RPR, RPS, N,
     1              TI, TOF, SI, SOF, CS, DPS, LPS10, HPS10)
      L10(4)=LPS10
      H1(4)=HPS10
      E1(4)=ES
      D1(4)=DPS
      CALL PLANET3(MG1, NPR, LR, FR, PR, ER, RR, RS, RPR, RPS, N,
     1              TI, TOF, SI, SOF, CR, DPR, LPR10, HPR10)
```

```
      L10(5)=LPR10
      H1(5)=HPR10
      E1(5)=ER
      D1(5)=DPR
26    CONTINUE
      CALL LIFE(L10,ISTEP,E1,NCOMP,LPLAN,EPLAN)
      HPLAN=LPLAN*16666.667/SOF
      RETURN
      END
C
C
C
C
      SUBROUTINE BEAR(MG1,CB,A,V,PB,PHIR,PHIS,RR,RS,RPR,RPS,N,FTT,
     *                TI,TO,SI,SOF,DB,LB10,HB10)
C
C
C     BEAR CALCULATES THE BASIC DYNAMIC CAPACITY OF ONE PLANET
C     BEARING AND THE L10 LIFE OF THE BEARING FOR THE GIVEN INPUT
C     TORQUE IN TERMS OF SUN REVOLUTIONS.
C
C
      REAL A,N,V,CB,PB,RR,RS,TI,RPR,RPS,LB10,PHIR,PHIS,
     1     TNPHIR,TNPHIS,MG1
C
C
C THE VARIABLES PASSED TO THE PROGRAM ARE:
C         CB--BASIC DYNAMIC CAPACITY OF A SINGLE BEARING
C         A--COMPOSITE BEARING LIFE ADJUSTMENT FACTOR
C         PB--LOAD LIFE EXPONENT OF THE BEARING
C         RPR--PITCH RADIUS OF PLANET MESHING WITH THE RING
C         RPS--PITCH RADIUS OF PLANET MESHING WITH THE SUN
C         RR--PITCH RADIUS OF THE RING
C         RS--PITCH RADIUS OF THE SUN
C         TI--INPUT TORQUE TO THE SUN
C         V--OUTER RACE ROTATION LOAD ADJUSTMENT FACTOR
C         PHIR--PRESSURE ANGLE OF RING MESH RADIANS
C         PHIS--PRESSURE ANGLE OF SUN MESH RADIANS
C         N--NUMBER OF PLANET BEARINGS IN THE TRANSMISSION
C THE VARIABLES PASSED FROM THE PROGRAM ARE:
C         DB--BASIC DYNAMIC CAPACITY OF ONE PLANET BEARING
C         LB10--L10 LIFE OF ONE PLANET BEARING SUN REVS
C
C CALCULATE THE TANGENTS OF THE PRESSURE ANGLES
C
```

```
      TNPHIR=SIN(PHIR)/COS(PHIR)
      TNPHIS=SIN(PHIS)/COS(PHIS)
C
C FS:  FORCE FROM SUN GEAR
      FS=TI/(N*RS)
C
C FR:  FORCE FROM RING GEAR
      FR=RPS/RPR*FS
C
C FTT:  TOTAL TANGENTIAL FORCE
      FTT=FS+FR
C
C FTR:  TOTAL RADIAL FORCE
      FTR=FR*TNPHIR-FS*TNPHIS
C
C FB:  TOTAL FORCE ON BEARING
      FB=V*SQRT(FTT**2+FTR**2)
C
C AMGB: LOAD CYCLES PER INPUT REVOLUTION
      AMGB=A*RPR/RR
C
C LB10: L10 LIFE OF ONE PLANET BEARING
      LB10=AMGB/MG1*(CB/FB)**PB
      HB10=LB10*16666.667/SOF
C
C DB:  THE BASIC DYNAMIC CAPACITY OF ONE PLANET BEARING
      DB=(AMGB/MG1)**(1.0/PB)*(CB*TO/FB)
      RETURN
      END
C
C
C
C
      SUBROUTINE SUN(MG1,NS,PHIS,B1SM,PS,ES,RR,RS,RPR,RPS,N,WDSM,
     1               TI,TO,SI,SOF,CS,LS,FS,DS,LS10,HS10)
C
C
C     SUN CALCULATES THE BASIC DYNAMIC CAPACITY OF THE SUN GEAR AND
C     THE L10 LIFE OF THE SUN GEAR FOR THE GIVEN INPUT TORQUE.
C
C
      REAL N,CS,DS,ES,NS,PS,RR,RS,TI,RPR,RPS,B1SM,LS10,
     1     PHIS,WDSM,LS,MG1
C
C
```

```
C VARIABLES WHICH ARE PASSED TO THE PROGRAM:
C         B1SM-MATERIAL CONSTANT FOR THE SUN-PLANET MESH
C         ES--WEIBULL EXPONENT OF THE SUN MESH
C         N--NUMBER OF PLANETS
C         NS--NUMBER OF TEETH ON SUN
C         PHIS--PRESSURE ANGLE OF THE SUN MESH RADIANS
C         PS--LOAD LIFE FACTOR OF ONE TOOTH OF THE MESH
C         RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
C         RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
C         RR--PITCH RADIUS OF THE RING
C         RS--PITCH RADIUS OF THE SUN
C         TI--INPUT TORQUE TO THE SUN
C         WDSM--EFFECTIVE FACE WIDTH OF THE MESH
C VARIABLES WHICH ARE PASSED FROM PROGRAM:
C         DS--BASIC DYNAMIC CAPACITY OF THE SUN GEAR
C         LS10--L10 LIFE OF THE SUN GEAR SUN REVS
C         CS--BASIC DYNAMIC CAPACITY OF ONE TOOTH OF THE MESH
C
C
C CALCULATE THE CAPACITY OF ONE TOOTH IN THE SUN MESH
C
      CS=BASCAP(RS,RPS,PHIS,WDSM,B1SM)
C
C FS: FORCE ON SUN GEAR
      FS=TI/(N*RS)
C
C LS: LIFE OF ONE TOOTH ON THE SUN GEAR
      LS=(CS/FS)**PS
C
C AMGS: LOAD CYCLES PER INPUT REVOLUTION
      AMGS=(RS*RPR)/(N*RR*RPS)
C
C LS10: L10 LIFE OF THE  SUN GEAR
      LS10=(1./NS)**(1./ES)*AMGS/MG1*LS
      HS10=16666.667*LS10/SOF
C
C DS: BASIC DYNAMIC CAPACITY OF THE SUN GEAR
      DS=(1.0/NS)**(1.0/ES/PS)*(AMGS/MG1)**(1./PS)*(CS/FS*TO)
      RETURN
      END

C
C
C
C
```

```
      SUBROUTINE PLANET1(MG1,ES,PS,ER,PR,RS,RR,RPS,RPR,TI,TO,SI,SOF,
     *                   N,NP,LS,FS,LR,FR,LP10,DP,HP10)
C
C
C     PLANET CALCULATES THE BASIC DYNAMIC CAPACITY OF A PLANET GEAR
C     AND THE L10 LIFE OF A PLANET GEAR FOR THE GIVEN INPUT TORQUE.
C
C
      REAL N,NP,LP10,LS,LR,LP,MG1
C
C
C VARIABLES WHICH ARE PASSED TO THE PROGRAM:
C        ES--WEIBULL EXPONENT OF THE PLANET-SUN MESH
C        PS--LOAD LIFE FACTOR OF THE PLANET-SUN MESH
C        ER--WEIBULL EXPONENT OF THE PLANET-RING MESH
C        PR--LOAD LIFE FACTOR OF THE PLANET-RING MESH
C        RS--PITCH RADIUS OF THE SUN
C        RR--PITCH RADIUS OF THE RING
C        RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
C        RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
C        TI--INPUT TORQUE TO THE SUN LB-IN
C        N--NUMBER OF PLANETS
C        NP--NUMBER OF TEETH ON THE PLANET
C        LS--LIFE OF ONE TOOTH IN THE PLANET-SUN MESH
C        FS--FORCE ON ONE TOOTH IN THE PLANET-SUN MESH
C        LR--LIFE OF ONE TOOTH IN THE PLANET-RING MESH
C        FR--FORCE ON ONE TOOTH IN THE PLANET-RING MESH
C VARIABLES WHICH ARE PASSED FROM PROGRAM:
C        DP--BASIC DYNAMIC CAPACITY OF THE PLANET
C        LP10--L10 LIFE OF THE PLANET SUN REVS
C
C
C AMGP: LOAD CYCLES PER INPUT REVOLUTION
      AMGP=RPR/RR
C
C LP: LIFE OF ONE TOOTH OF PLANET DUE TO DUAL LOADING
      LP=(LS*LR)/(LS**ES+LR**ES)**(1./ES)
C
C LP10: LIFE OF STEPPED PLANET GEAR
      LP10=(1.0/NP)**(1.0/ES)*AMGP/MG1*LP
      HP10=16666.667*LP10/SOF
C
C DP: DYNAMIC CAPACITY OF PLANET GEAR
      DP=(1.0/NP)**(1.0/ES/PS)*(AMGP/MG1)**(1.0/PS)
     1*LP**(1.0/PS)*TO
```

```
      RETURN
      END
      SUBROUTINE PLANET2(MG1,NP,LS,FS,PS,ES,RR,RS,RPR,RPS,N,
     1                   TI,TO,SI,SOF,CS,DPS,LPS10,HPS10)
C
C
C     PLANET2 CALCULATES THE BASIC DYNAMIC CAPACITY OF THE
C     PANET-SUN GEAR AND THE L10 LIFE OF THE PANET-SUN GEAR
C     FOR THE GIVEN INPUT TORQUE.
C
C
      REAL N,CS,DPS,ES,NP,PS,RR,RS,TI,RPR,RPS,LPS10,
     1     LS,MG1
C
C
C VARIABLES WHICH ARE PASSED TO THE PROGRAM:
C         LS--LIFE OF ONE TOOTH IN THE PLANET-SUN MESH
C         FS--FORCE ON ONE TOOTH IN THE PLANET-SUN MESH
C         ES--WEIBULL EXPONENT OF THE SUN MESH
C         N--NUMBER OF PLANETS
C         NS--NUMBER OF TEETH ON SUN
C         PS--LOAD LIFE FACTOR OF ONE TOOTH OF THE MESH
C         RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
C         RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
C         RR--PITCH RADIUS OF THE RING
C         RS--PITCH RADIUS OF THE SUN
C         TI--INPUT TORQUE TO THE SUN
C VARIABLES WHICH ARE PASSED FROM PROGRAM:
C         DS--BASIC DYNAMIC CAPACITY OF THE SUN GEAR
C         LS10--L10 LIFE OF THE SUN GEAR SUN REVS
C
C
C AMGP: LOAD CYCLES PER INPUT REVOLUTION
      AMGP=RPR/RR
C
C LS10: L10 LIFE OF THE  SUN GEAR
      LPS10=(1./NP)**(1./ES)*AMGP/MG1*LS
      HPS10=LPS10*16666.667/SOF
C
C DS: BASIC DYNAMIC CAPACITY OF THE SUN GEAR
      DPS=(1.0/NP)**(1.0/ES/PS)*(AMGP/MG1)**(1./PS)*(CS/FS*TO)
      RETURN
      END
C
C
```

```
      SUBROUTINE PLANET3(MG1,NP,LR,FR,PR,ER,RR,RS,RPR,RPS,N,
     1                   TI,TO,SI,SOF,CR,DPR,LPR10,HPR10)
C
C
C     PLANET3 CALCULATES THE BASIC DYNAMIC CAPACITY OF THE
C     PLANET-RING GEAR AND THE L10 LIFE OF THE PLANET-RING
C     GEAR FOR THE GIVEN INPUT TORQUE.
C
C
      REAL N,CR,DR,ER,NP,PR,RR,RS,TI,RPR,RPS,LPR10,
     1     LR,MG1
C
C
C VARIABLES WHICH ARE PASSED TO THE PROGRAM:
C        LR--LIFE OF ONE TOOTH IN THE PLANET-RING MESH
C        FR--FORCE ON ONE TOOTH IN THE PLANET-RING MESH
C        ER--WEIBULL EXPONENT OF THE RING MESH
C        NP--NUMBER OF TEETH ON ONE PLANET
C        NR--NUMBER OF TEETH ON RING
C        PR--LOAD LIFE FACTOR OF ONE TOOTH OF THE MESH
C        RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
C        RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
C        RR--PITCH RADIUS OF THE RING
C        RS--PITCH RADIUS OF THE SUN
C        TI--INPUT TORQUE TO THE SUN
C VARIABLES WHICH ARE PASSED FROM PROGRAM:
C        DPR--BASIC DYNAMIC CAPACITY OF THE RING GEAR
C        LPR10--L10 LIFE OF THE RING GEAR SUN REVS
C
C
C AMGP: LOAD CYCLES PER INPUT REVOLUTION
      AMGP=RPR/RR
C
C LR10: L10 LIFE OF THE RING GEAR
      LPR10=(1./NP)**(1./ER)*AMGP/MG1*LR
      HPR10=LPR10*16666.667/SOF
C
C DR: THE BASIC DYNAMIC CAPACITY OF THE RING GEAR
      DPR=(1./NP)**(1./ER/PR)*(AMGP/MG1)**(1./PR)*CR*TO/FR
      RETURN
      END
C
C
      SUBROUTINE RING(MG1,NR,PHIR,B1RM,PR,ER,RR,RS,RPR,RPS,N,WDRM,
     1                TI,TO,SI,SOF,CR,LR,FR,DR,LR10,HR10)
```

```
C
C
C      RING CALCULATES THE BASIC DYNAMIC CAPACITY OF THE RING GEAR AND
C      THE L10 LIFE OF THE RING GEAR FOR THE GIVEN INPUT TORQUE.
C
C
       REAL N, CR, DR, ER, NR, PR, RR, RS, TI, RPR, RPS, B1RM, LR10,
     1      PHIR, WDRM, LR, MG1
C
C
C VARIABLES WHICH ARE PASSED TO THE PROGRAM:
C         B1RM--MATERIAL CONSTANT OF THE RING-PLANET MESH
C         ER--WEIBULL EXPONENT OF THE RING MESH
C         NP--NUMBER OF TEETH ON ONE PLANET
C         NR--NUMBER OF TEETH ON RING
C         PHIR--PRESSURE ANGLE OF THE RING MESH RADIANS
C         PR--LOAD LIFE FACTOR OF ONE TOOTH OF THE MESH
C         RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
C         RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
C         RR--PITCH RADIUS OF THE RING
C         RS--PITCH RADIUS OF THE SUN
C         TI--INPUT TORQUE TO THE SUN
C         WDRM--EFFECTIVE FACE WIDTH OF THE GEARS
C VARIABLES WHICH ARE PASSED FROM PROGRAM:
C         DR--BASIC DYNAMIC CAPACITY OF THE RING GEAR
C         LR10--L10 LIFE OF THE RING GEAR SUN REVS
C         CR--BASIC DYNAMIC CAPACITY OF ONE TOOTH OF THE RING MESH
C
C
C CALCULATE THE CAPACITY OF ONE TOOTH IN THE RING MESH
C THE -RR IN FUNCTION BASCAP INDICATES AN INTERNAL GEAR MESH.
C
      CR=BASCAP(RPR, -RR, PHIR, WDRM, B1RM)
C
C FR: FORCE ON THE RING GEAR
      FR=RPS*TI/(RPR*RS*N)
C
C LR: LIFE OF ONE TOOTH ON THE RING GERA
      LR=(CR/FR)**PR
C
C AMGR: LOAD CYCLES PER INPUT REVOLUTION
      AMGR=1./N
C
C LR10: L10 LIFE OF THE RING GEAR
      LR10=(1./NR)**(1./ER)*AMGR/MG1*LR
```

```
      HR10=LR10*16666.667/SOF
C
C DR:  THE BASIC DYNAMIC CAPACITY OF THE RING GEAR
      DR=(1./NR)**(1./ER/PR)*(AMGR/MG1)**(1./PR)*CR*TO/FR
      RETURN
      END
C
C
      SUBROUTINE PLANIN(CB,A,V,EB,PB,N,NCOMP,PDS,PDR,NS,PHIS,PHIS1,
     1PHIR,PHIR1,WDSM,ES,PS,B1SM,ISTEP,NPS,NPR,NR,WDRM,ER,PR,B1RM,
     2RPR,RPS,RR,RS)
      CHARACTER*9 DATAFILE
      REAL N,NCOMP(5),NS,NPS,NPR,NR
      INTEGER NO,YES,ANSWER
      PARAMETER (NO='NO',YES='YES')
      WRITE(1,300)
300   FORMAT(///' PLANETARY GEAR UNIT INPUTS'///)
      WRITE(1,999)
999   FORMAT('DO YOU WISH TO USE A DATA FILE (YES OR NO)')
      READ(1,110)ANSWER
      IF(ANSWER.EQ.NO)GO TO 501
      WRITE(1,502)
502   FORMAT('WHAT IS THE NAME OF THE INPUT FILE')
      READ(1,503)DATAFILE
503   FORMAT(A)
      OPEN(UNIT=56,FILE=DATAFILE,STATUS='UNKNOWN')
      NRE=56
      GO TO 500
501   NRE=1
500   CONTINUE
C
C
C
      WRITE(1,1000)
      READ(NRE,*)CB
      WRITE(1,1010)
      READ(NRE,*)A
      WRITE(1,1020)
      READ(NRE,*)V
      WRITE(1,1030)
      READ(NRE,*)EB
      WRITE(1,1040)
      READ(NRE,*)PB
      WRITE(1,1050)
      READ(NRE,*)N
```

```
NCOMP(1)=N
NCOMP(2)=1.
NCOMP(3)=1.
NCOMP(4)=N
NCOMP(5)=N
WRITE(1,1060)
READ(NRE,110)ANSWER
IF(ANSWER.EQ.YES)WRITE(1,1070)
IF(ANSWER.EQ.NO)WRITE(1,1080)
READ(NRE,*)PDS
IF(ANSWER.EQ.YES)PDR=PDS
IF(ANSWER.EQ.NO)READ(NRE,*)PDR
WRITE(1,1090)
READ(NRE,*)NS
WRITE(1,1100)
READ(NRE,110)ANSWER
IF(ANSWER.EQ.YES)WRITE(1,1110)
IF(ANSWER.EQ.NO)WRITE(1,1120)
READ(NRE,*)PHIS
IF(ANSWER.EQ.YES)PHIR=PHIS
IF(ANSWER.EQ.NO)READ(NRE,*)PHIR
PHIS1=PHIS*3.1415927/180.0
PHIR1=PHIR*3.1415927/180.0
WRITE(1,1130)
READ(NRE,*)WDSM
WRITE(1,1140)
READ(NRE,*)ES
WRITE(1,1150)
READ(NRE,*)PS
WRITE(1,1160)
READ(NRE,*)B1SM
WRITE(1,1170)
READ(NRE,110)ANSWER
ISTEP=4
IF(ANSWER.EQ.NO)WRITE(1,1180)
IF(ANSWER.EQ.YES)WRITE(1,1190)
IF(ANSWER.EQ.YES)ISTEP=5
READ(NRE,*)NPS
IF(ANSWER.EQ.NO)NPR=NPS
IF(ANSWER.EQ.YES)READ(NRE,*)NPR
WRITE(1,1200)
READ(NRE,*)NR
WRITE(1,1210)
READ(NRE,*)WDRM
WRITE(1,1220)
```

```
      READ(NRE,*)ER
      WRITE(1,1230)
      READ(NRE,*)PR
      WRITE(1,1240)
      READ(NRE,*)B1RM
      CLOSE(56)
C
C
C
      RPR=NPR/2.0/PDR
      RPS=NPS/2.0/PDS
      RR=NR/2.0/PDR
      RS=NS/2.0/PDS
C
C INPUT WRITE FORMATS
C
110   FORMAT(1A4)
1000  FORMAT(20X,'PLANETARY TRANSMISSION RELIABILTY ANALYSIS'//,
     1       20X,'(ALL NUMERICAL INPUT MUST BE IN F-FORMAT)'//,
     2       5X,'WHAT IS THE BASIC DYNAMIC CAPACITY OF ONE PLANET',
     3       ' BEARING? (LB)')
1010  FORMAT(5X,'WHAT IS THE COMPOSITE LIFE ADJUSTMENT FACTOR?')
1020  FORMAT(5X,'WHAT IS THE OUTER RACE ROTATION FACTOR?')
1030  FORMAT(5X,'WHAT IS THE WEIBULL FACTOR FOR THE BEARINGS?')
1040  FORMAT(5X,'WHAT IS THE LOAD-LIFE FACTOR FOR THE BEARINGS?')
1050  FORMAT(5X,'HOW MANY PLANET BEARINGS ARE IN THE TRANSMISSION?')
1060  FORMAT(5X,'IS THE DIAMETRAL PITCH THE SAME FOR BOTH MESHES?')
1070  FORMAT(5X,'WHAT IS THE DIAMETRAL PITCH OF THE TRANSMISSION?',
     1       ' (TEETH/IN)')
1080  FORMAT(5X,'ENTER THE DIAMETRAL PITCH OF THE SUN MESH FIRST, /,
     1       5X,'THEN, ENTER THE DIAMETRAL PITCH OF THE RING MESH. ',
     2       ' (TEETH/IN)')
1090  FORMAT(5X,'HOW MANY TEETH DOES THE SUN GEAR HAVE ON IT?')
1100  FORMAT(5X,'IS THE PRESSURE ANGLE FOR THE SUN MESH AND'/,
     1       5X,'THE RING MESH THE SAME?')
1110  FORMAT(5X,'WHAT IS THE PRESSURE ANGLE? (DEG)')
1120  FORMAT(5X,'ENTER THE PRESSURE ANGLE FOR THE SUN MESH FIRST, '/,
     1       5X,'THEN ENTER THE PRESSURE ANGLE OF THE RING MESH.  (DEG)')
1130  FORMAT(5X,'WHAT IS THE FACE WIDTH OF THE SUN MESH? (IN)')
1140  FORMAT(5X,'WHAT IS THE WEIBULL EXPONENT OF THE SUN MESH?')
1150  FORMAT(5X,'WHAT IS THE LOAD-LIFE FACTOR OF THE SUN MESH?')
1160  FORMAT(5X,'WHAT IS THE MATERIAL CONSTANT OF THE SUN MESH? (PSI)')
1170  FORMAT(5X,'DOES THE TRANSMISSION HAVE STEPPED PLANETS?')
1180  FORMAT(5X,'HOW MANY TEETH DOES ONE PLANET GEAR HAVE?')
1190  FORMAT(5X,'ENTER THE NUMBER OF TEETH ON ONE PLANET MESHED'/,
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```
     1        5X,'WITH THE SUN, THEN ENTER THE NUMBER OF TEETH ON THE'/,
     2        5X,'PLANET MESHED WITH THE RING.')
1200  FORMAT(5X,'HOW MANY TEETH ARE ON THE RING GEAR?')
1210  FORMAT(5X,'WHAT IS THE FACE WIDTH OF THE RING GEAR MESH? (IN)')
1220  FORMAT(5X,'WHAT IS THE WEIBULL EXPONENT OF THE RING GEAR MESH?')
1230  FORMAT(5X,'WHAT IS THE LOAD-LIFE FACTOR OF THE RING GEAR MESH?')
1240  FORMAT(5X,'WHAT IS THE MATERIAL CONSTANT OF THE RING GEAR MESH?',
     1        ' (TEETH/IN)')
      RETURN
      END
C
      SUBROUTINE PLANOT(ISTEP,N,V,CB,FB,NS,PDS,PHIS,WDSM,B1SM,FS,
     1NR,PDR,PHIR,WDRM,B1RM,FR,NP,NPS,NPR,TI,TOF,SI,SOF,FTT,
     2D1,P1,L1,H1,E1)
      REAL N,NS,NR,NP,NPS,NPR,D1(5),P1(5),L1(5),E1(5),H1(5)
      WRITE(1,5049)TI,TOF,SI,SOF
      WRITE(1,5002)
      DB1=D1(1)*FTT/TOF
      WRITE(1,5051)N,V,CB,DB1,FTT
      WRITE(1,5000)
      DS1=D1(2)*FS/TOF
      WRITE(1,5050)NS,PDS,PHIS,WDSM,B1SM,DS1,FS
      WRITE(1,5001)
      DR1=D1(3)*FR/TOF
      WRITE(1,5050)NR,PDR,PHIR,WDRM,B1RM,DR1,FR
      WRITE(1,5003)
      DP1=D1(4)*FS/TOF
      IF(ISTEP.EQ.5)GOTO10
      WRITE(1,5050)NPS,PDS,PHIS,WDSM,B1SM,DP1,FS
      GOTO20
10    DPS1=D1(4)*FS/TOF
      WRITE(1,5004)
      WRITE(1,5050)NPS,PDS,PHIS,WDSM,B1SM,DPS1,FS
      DPR1=D1(5)*FR/TOF
      WRITE(1,5005)
      WRITE(1,5050)NPR,PDR,PHIR,WDRM,B1RM,DPR1,FR
20    CONTINUE
      WRITE(1,4999)
      WRITE(1,5002)
      CALL DPLHE(D1(1),P1(1),L1(1),H1(1),E1(1))
      WRITE(1,5000)
      CALL DPLHE(D1(2),P1(2),L1(2),H1(2),E1(2))
      WRITE(1,5001)
      CALL DPLHE(D1(3),P1(3),L1(3),H1(3),E1(3))
      IF(ISTEP.EQ.5)GOTO11
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      WRITE(1,5003)
      CALL DPLHE(D1(4),P1(4),L1(4),H1(4),E1(4))
      GOTO21
11    WRITE(1,5004)
      CALL DPLHE(D1(4),P1(4),L1(4),H1(4),E1(4))
      WRITE(1,5005)
      CALL DPLHE(D1(5),P1(5),L1(5),H1(5),E1(5))
21    CONTINUE
4998  FORMAT(////
     1'       PLANETARY GEAR UNIT'//)
4999  FORMAT(////
     *'            DYNAMIC CAPACITY AND LIFE IN TERMS OF'/
     *'                       OUTPUT TORQUE AND SPEED'//)
5000  FORMAT('    SUN GEAR'/)
5001  FORMAT('    RING GEAR'/)
5002  FORMAT('    PLANET BEARING'/)
5003  FORMAT('    PLANET GEAR'/)
5004  FORMAT('    PLANET-SUN GEAR'/)
5005  FORMAT('    PLANET-RING GEAR'/)
5049  FORMAT(///
     1'   INPUT TORQUE.............................',F14.5,' LB-IN'/
     2'   OUTPUT TORQUE............................',F14.5,' LB-IN'/
     3'   INPUT SPEED..............................',F14.5,' RPM'/
     4'   OUTUT SPEED..............................',F14.5,' RPM'/)
5050  FORMAT(/
     1'   NUMBER OF TEETH..........................',F14.5/
     2'   PITCH OF THE MESH........................',F14.5/
     3'   PRESSURE ANGLE...........................',F14.5,' DEG'/
     4'   FACE WIDTH...............................',F14.5,' IN'/
     5'   MATERIAL CONSTANT OF THE MESH............',F14.5,' PSI'/
     6'   DYNAMIC CAPACITY ........................',F14.5,' LBS'/
     7'   FORCE ON GEAR TOOTH......................',F14.5,' LBS'/)
5051  FORMAT(/
     1'   NUMBER OF PLANETS........................',F14.5,/
     2'   ROTATIONAL FACTOR........................',F14.5,/
     3'   DYNAMIC CAPACITY (CATALOG VALUE)........',F14.5,' LBS'/
     4'   DYNAMIC CAPACITY (SYSTEM VALUE).........',F14.5,' LBS'/
     5'   TOTAL FORCE.............................',F14.5,' LBS'/)
      RETURN
      END
      SUBROUTINE SPBVCA(
     1TI,TOF,SI,SOF,MG,MG1,NP,NG,
     2AO,GAMMA1,ROT,SPR,PHE1,PHSI1,ZZ1,
     3PTL,AP,BP,RP,GTL,AG,BG,RG,
     4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,EGP1,ADJP1,
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     5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,EGP2,ADJP2,
     6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,EGG1,ADJG1,
     7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,EGG2,ADJG2,
     8F,E,PG,EG,RPD,RGD,
     9PXP,PYP,PZP,TOTFOR,PXG,PYG,PZG,TOTFOR,
     1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
     2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
     3L10P1,H10P1,TOFORP1,PGP1,BDCAP10,BDCAP10T,
     4L10P2,H10P2,TOFORP2,PGP2,BDCAP20,BDCAP20T,
     5L10G1,H10G1,TOFORG1,PGG1,BDCAG10,BDCAG10T,
     6L10G2,H10G2,TOFORG2,PGG2,BDCAG20,BDCAG20T,
     7LP10,HP10,DCAP,DCAPT,
     8LG10,HG10,DCAG,DCAGT,
     9LSB,HSB,ESB)
      INTEGER PTL,GTL
      REAL L10P1,L10P2,L10G1,L10G2,LP10,LG10,LSB,LL(6),EE(6),NCOMP(6)
      REAL MG,MG1,NP,NG,NBP1,NBP2,NBG1,NBG2
      DATA NCOMP/1.,1.,1.,1.,1.,1./
C-----------------------------------------------------------------------
C     CALCULATION OF THE LOADS TRANSMITTED FROM THE PINION
C-----------------------------------------------------------------------
      CALL GPSPR(TI,AO,F,GAMMA1,ROT,SPR,PHE1,PHSI1,PXP,PYP,PZP)
      TOTFOR=SQRT(PXP**2+PYP**2+PZP**2)
C-----------------------------------------------------------------------
C     CALCULATION OF THE LOADS TRANSMITTED TO THE GEAR FROM EACH PINION
C-----------------------------------------------------------------------
      TOUT=MG*TI
      ROT1=-ROT
      SPR1=SPR
      CALL GPSPR(TOUT,AO,F,ZZ1,ROT1,SPR1,PHE1,PHSI1,PXG,PYG,PZG)
C-----------------------------------------------------------------------
C     CHECK CASE FOR BEARING POSITION AND CALCULATE THE LOADS
C     ON THE BEARINGS TRANSMITTED FROM THE  RIGHT PINION
C-----------------------------------------------------------------------
      IF(PTL.EQ.2)GO TO 18
      R1XP=PXP
      R2XP=0.0
      GO TO 19
18    R1XP=0.0
      R2XP=PXP
19    CONTINUE
      CALL BLC1(PXP,PYP,PZP,AP,BP,RP,R1YP,R1ZP,R2YP,R2ZP)
C-----------------------------------------------------------------------
C     CHECK CASE FOR BEARING POSITION CALCULATE THE LOADS
C     ON THE BEARINGS TRANSMITTED FROM THE GEAR DUE TO THE PINION
```

```
C-----------------------------------------------------------------------
      IF(QTL.EQ.2)GO TO 22
      R1XG=PXG
      R2XG=0.0
      GO TO 23
22    R1XG=0.0
      R2XG=PXG
23    CONTINUE
      CALL BLC1(PXG,PYG,PZG,AG,BG,RG,R1YG,R1ZG,R2YG,R2ZG)
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF PINION BEARING #1
C-----------------------------------------------------------------------
      CALL BDCAP(ITYPEP1,R1XP,R1YP,R1ZP,RFP1,NBP1,DP1,ACP1,SOF,ADJP1
     *,BDCAP1,L10P1,H10P1,MG,MG1,AK1,TOFORP1,PGP1,BDCAP10)
      BDCAP10T=BDCAP10*TOF/TOFORP1
      LL(2)=L10P1
      EE(2)=EGP1
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF PINION BEARING #2
C-----------------------------------------------------------------------
      CALL BDCAP(ITYPEP2,R2XP,R2YP,R2ZP,RFP2,NBP2,DP2,ACP2,SOF,ADJP2
     *,BDCAP2,L10P2,H10P2,MG,MG1,AK2,TOFORP2,PGP2,BDCAP20)
      BDCAP20T=BDCAP20*TOF/TOFORP2
      LL(3)=L10P2
      EE(3)=EGP2
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF GEAR BEARING #1
C-----------------------------------------------------------------------
      CALL BDCAP(ITYPEG1,R1XG,R1YG,R1ZG,RFG1,NBG1,DG1,ACG1,SOF,ADJG1
     *,BDCAG1,L10G1,H10G1,1.,MG1,AK3,TOFORG1,PGG1,BDCAG10)
      BDCAG10T=BDCAG10*TOF/TOFORG1
      LL(5)=L10G1
      EE(5)=EGG1
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF GEAR BEARING #2
C-----------------------------------------------------------------------
      CALL BDCAP(ITYPEG2,R2XG,R2YG,R2ZG,RFG2,NBG2,DG2,ACG2,SOF,ADJG2
     *,BDCAG2,L10G2,H10G2,1.,MG1,AK4,TOFORG2,PGG2,BDCAG20)
      BDCAG20T=BDCAG20*TOF/TOFORG2
      LL(6)=L10G2
      EE(6)=EGG2
C-----------------------------------------------------------------------
C     CALCULATE THE LIFE OF THE GEAR
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
```

```
      CALL SET(PHE1,F,E,MG,MG1,NP,NG,SOF,LP10,HP10,LG10,
     *HG10,PG,EG,TOTFOR,RPD,RGD,DCAP,DCAG,TOTFOR)
      DCAPT=DCAP*TOF/TOTFOR
      DCAGT=DCAG*TOF/TOTFOR
      LL(1)=LP10
      LL(4)=LG10
      EE(1)=EG
      EE(4)=EG
C-----------------------------------------------------------------
C     CALCULATE THE LIFE OF THE TRANSMISSION
C-----------------------------------------------------------------
      CALL LIFE(LL,6,EE,NCOMP,LSB,ESB)
      HSB=LSB*16666.667/SOF
      RETURN
      END
C---------------------------------------------------------------
      SUBROUTINE SET(PHE,F,E,MG,MG1,NP,NG,SPEED2,LP10,HP10,LG10
     *,HG10,PG,EG,FOR,R1,R2,DCAP,DCAG,FE)
C---------------------------------------------------------------
C     CALCULATION OF THE LIFE OF THE PINION AND GEAR MESH
C---------------------------------------------------------------
C
C INPUTS
C
C     PHE   -PRESSURE ANGLE OF THE MESH (RADIANS)
C     F     -FACE WIDTH (IN)
C     E     -MESH MATERIAL CONSTANT (PSI)
C     MG    -GEAR RATIO
C     NP    -NUMBER OF TEETH OF THE PINION
C     NG    -NUMBER OF TEETH OF THE GEAR
C     SPEED2-SPEED OF OUTPUT SHAFT
C     PG    -MESH MATERIAL CONSTANT
C     EG    -MESH WEIBULL EXPONENT
C     FOR   -TOTAL FORCE TRANSMITTED
C     R1    -REFERENCE PLANE RADIUS OF SPIRAL BEVEL PINION (IN)
C     R2    -REFERENCE PLANE RADIUS OF SPIRAL BEVEL GEAR (IN)
C
C OUTPUT
C
C     LP10  -THE L10 LIFE OF THE PINION (CYCLES)
C     HP10  -THE L10 LIFE OF THE PINION (HOURS)
C     LG10  -THE L10 LIFE OF THE GEAR (CYCLES)
C     HG10  -THE L10 LIFE OF THE GEAR (HOURS)
C     DCAP  -THE DYNAMIC CAPACITY OF THE PINION (LBS)
C     DCAG  -THE DYNAMIC CAPACITY OF THE GEAR (LBS)
```

```
C       FOR    -FORCE ON THE PINION
C       FE     -FORCE ON THE GEAR
C
        REAL NP,NG,MG,MG1,LP10,LG10,LP10T,LG10T
        F1=.5*F
        CBG=BASCAP(R1,R2,PHE,F1,E)
C
C       CALCULATE LIFE OF GEAR TEETH
C
        LP10T=(CBG/FOR)**PG
        LG10T=(CBG/FE)**PG
        VEG=1./EG
        VPG=1./PG
C
C       CALCULATE LIFE OF PINION AND GEAR
C
        LP10=(1./NP)**VEG/MG/MG1*LP10T
        HP10=LP10*16666.666/SPEED2
        LG10=(1./NG)**VEG/MG1*LG10T
        HG10=LG10*16666.666/SPEED2
C
C       CALCULATE BASIC DYNAMIC CAPACITY OF PINION AND GEAR
C
        DCAP=((1./NP)**VEG/MG/MG1)**VPG*CBG
        DCAG=((1./NG)**VEG/MG1)**VPG*CBG
        RETURN
        END
        SUBROUTINE SPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,EG,PG,
       1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
       2BDCAP1,RFP1,EGP1,ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,EGP2,
       3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,EGG1,
       4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,EGG2,MG,GAMMA1,GAMMA,ZZ,
       5ZZ1,DP,DG,RPD,RP,RGD,RG,HK,AOG,AOP,HT,BOG,BOP,PD,
       6ADJP1,ADJP2,ADJG1,ADJG2)
C
C       SPIRAL BEVEL INPUT
C
        CHARACTER*9 DATAFILE
        INTEGER NO,YES,ANSWER,CASEP,CASEG,PTL,GTL
        REAL NP,NG,MG,NBP1,NBP2,NBG1,NBG2
        PARAMETER(NO='NO',YES='YES')
        PII=3.141592654
        WRITE(1,300)
300     FORMAT(///' SPIRAL BEVEL GEAR UNIT INPUTS'//)
        WRITE(1,999)
```

```
      READ(1,99)ANSWER
      IF(ANSWER.EQ.NO)GO TO 501
      WRITE(1,502)
502   FORMAT('WHAT IS THE NAME OF THE INPUT FILE')
      READ(1,503)DATAFILE
503   FORMAT(A)
      OPEN(UNIT=55,FILE=DATAFILE,STATUS='UNKNOWN')
      NRE=55
      GO TO 500
501   NRE=1
500   CONTINUE
      CALL GEARINP(NRE,NP,NG,AO,PHE,F,PHSI,ROT,SPR,
     *THETA,E,EG,PG)
      CALL GEAROUT(NP,NG,AO,PHE,F,PHSI,ROT,SPR,
     *THETA,E,EG,PG)
      WRITE(1,1070)
      READ(NRE,*)LL1
      IF(LL1.EQ.1)GOTO500
      PHE1=PHE*PII/180.
      PHSI1=PHSI*PII/180.
      TI=TI*ROT
      THETA1=THETA*PII/180.
C
C
C ENTERING THE VALUES FOR THE PINION AND ITS BEARINGS
C
C
      WRITE(1,1074)
600   CONTINUE
      CALL CASEINP(NRE,CASEP,PTL,AP,BP)
      CALL CASEOUT(CASEP,PTL,AP,BP)
      WRITE(1,1070)
      READ(NRE,*)L1
      IF(L1.EQ.1)GOTO600
601   CONTINUE
      WRITE(1,1040)
      CALL BEARINP(NRE,ITYPEP1,NBP1,DP1,ACP1,AK1,BDCAP1,RFP1,EQP1,ADJP1)
      CALL BEAROUT(ITYPEP1,NBP1,DP1,ACP1,AK1,BDCAP1,RFP1,EQP1,ADJP1)
      WRITE(1,1070)
      READ(NRE,*)L2
      IF(L2.EQ.1)GCTO601
602   CONTINUE
      WRITE(1,1045)
      CALL BEARINP(NRE,ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,EQP2,ADJP2)
      CALL BEAROUT(ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,EQP2,ADJP2)
```

```
      WRITE(1,1070)
      READ(NRE,*)L3
      IF(L3.EQ.1)GOTO602
C
C
C     INPUT THE GEAR AND ITS SUPPORTING BEARINGS
C
C
      WRITE(1,1075)
603   CONTINUE
      CALL CASEINP(NRE,CASEG,GTL,AG,BG)
      CALL CASEOUT(CASEG,GTL,AG,BG)
      WRITE(1,1070)
      READ(NRE,*)L4
      IF(L4.EQ.1)GOTO603
604   CONTINUE
      WRITE(1,1040)
      CALL BEARINP(NRE,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,EGG1,ADJG1)
      CALL BEAROUT(ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,EGG1,ADJG1)
      WRITE(1,1070)
      READ(NRE,*)L5
      IF(L5.EQ.1)GOTO604
605   CONTINUE
      WRITE(1,1045)
      CALL BEARINP(NRE,ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,EGG2,ADJG2)
      CALL BEAROUT(ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,EGG2,ADJG2)
      WRITE(1,1070)
      READ(NRE,*)L6
      IF(L6.EQ.1)GOTO605
      CLOSE(55)
C-----------------------------------------------------------------------
C     CALCULATION OF GEAR RATIO AND OUTPUT SPEED
C-----------------------------------------------------------------------
      MG=NG/NP
      SPEED2=SPEED/MG
C-----------------------------------------------------------------------
C     CALCULATION OF GAMMA
C-----------------------------------------------------------------------
      GAMMA1=ATAN(SIN(THETA1)/(MG+COS(THETA1)))
      GAMMA=GAMMA1*180./PII
      ZZ=THETA-GAMMA
      ZZ1=ZZ*PII/180.
C-----------------------------------------------------------------------
C     CALCULATION OF PITCH DIAMETER OF GEAR AND PINION
C     AND REFERENCE PITCH DIAMETER OF GEAR AND PINION
```

AD-A172 564 SYSTEM LIFE AND RELIABILITY MODELING FOR HELICOPTER TRANSMISSIONS(U) AKRON UNIV OH DEPT OF MECHANICAL ENGINEERING M SAVAGE ET AL APR 86 NASA-CR-3967 NAG3-55

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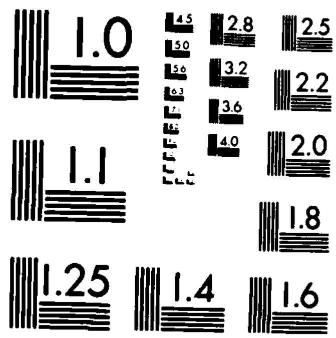

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
C-----------------------------------------------------------------------
      DP=(AO-F/2.)*(2.*SIN(GAMMA1))
      DG=(AO-F/2.)*(2.*SIN(ZZ1))
      PD=NG/DG
      RPD=DP*.5/COS(GAMMA1)
      RP=DP*.5
      RGD=DG*.5/COS(ZZ1)
      RG=DG*.5
C-----------------------------------------------------------------------
C     WORKING DEPTH
C-----------------------------------------------------------------------
      HK=1.70/PD
C-----------------------------------------------------------------------
C     ADDENDUM OF GEAR AND PINION
C-----------------------------------------------------------------------
      AOG=0.46/PD+0.390/(PD*MG**2)
      AOP=HK-AOG
C-----------------------------------------------------------------------
C     WHOLE DEPTH
C-----------------------------------------------------------------------
      IF(PD.LT.10.)GO TO 50
      HT=1.888/PD
      GOTO51
50    HT=1.888/PD+.005
51    CONTINUE
C-----------------------------------------------------------------------
C     DEDENDUM OF THE GEAR AND PINION
C-----------------------------------------------------------------------
      BOG=HT-AOG
      BOP=HT-AOP
C-----------------------------------------------------------------------
      BOP=HT-AO
999   FORMAT('DO YOU WISH TO USE A DATA SET'/
     *'ANSWER YES OR NO')
1040  FORMAT('PINION BEARING #1')
1045  FORMAT('PINION BEARING #2')
1046  FORMAT('GEAR BEARING #1')
1047  FORMAT('GEAR BEARING #2')
1070  FORMAT('DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS'/
     *'ENTER 1 TO CHANGE')
1074  FORMAT('PINION MOUNTING')
1075  FORMAT('GEAR MOUNTING')
99    FORMAT(1A4)
      RETURN
      END
```

```
      SUBROUTINE SPBVOT(PD,PHE,PHSI,SPR,F,AO,SI,SOF,ROT,TI,TOF,THETA,
     1NP,GAMMA,DP,RPD,AOP,BOP,PD,
     2PXP,PYP,PZP,TOTFOR,DCAP,CASEP,AP,BP,
     3R1XP,R1YP,R1ZP,TOFORP1,BDCAP1O,
     4R2XP,R2YP,R2ZP,TOFORP2,BDCAP2O,
     5NG,ZZ,DG,RGD,AOG,BOG,
     6PXG,PYG,PZG,TOTFOR,DCAG,CASEG,AG,BG,
     7R1XG,R1YG,R1ZG,TOFORG1,BDCAG1O,
     8R2XG,R2YG,R2ZG,TOFORG2,BDCAG2O,
     9D1,P1,L1,H1,E1)
C -----------------------------------------------------------------
C     PRINT OUT RESULTS
C -----------------------------------------------------------------
      REAL NP,NG,D1(6),P1(6),L1(6),H1(6),E1(6)
      INTEGER CASEP,CASEG
      WRITE(1,1000)
1000  FORMAT(///
     1'          SPIRAL BEVEL GEAR UNIT'////)
      WRITE(1,1200)PD,PHE,PHSI,SPR,F,AO,SI,SOF
     *,ROT,TI,TOF,THETA
      WRITE(1,1209)
      WRITE(1,1202)NP,GAMMA,DP,RPD,AOP,BOP,PXP,PYP,PZP
     *,TOTFOR,DCAP
      WRITE(1,1205)CASEP,AP,BP,R1XP,R1YP,R1ZP
     *,TOFORP1,BDCAP1O,R2XP,R2YP,R2ZP,TOFORP2,BDCAP2O
      WRITE(1,1210)
      WRITE(1,1202)NG,ZZ,DG,RGD,AOG,BOG,PXG,PYG,PZG,
     *TOTFOR,DCAG
      WRITE(1,1205)CASEG,AG,BG,R1XG,R1YG,R1ZG
     *,TOFORG1,BDCAG1O,R2XG,R2YG,R2ZG,TOFORG2,BDCAG2O
1200  FORMAT(//'     GEAR MESH CHARACTERISTICS          '//
     *' PITCH                                       ',F8.2/
     *' NORMAL PRESSURE ANGLE                       ',F8.2/
     *' SPIRAL ANGLE                                ',F8.2/
     *' HAND OF THE SPIRAL OF THE PINION GEAR       ',F8.3/
     *' FACE WIDTH                                  ',F8.3,' IN'/
     *' CONE DISTANCE                               ',F8.3,' IN'/
     *' INPUT SPEED OF THE PINION SHAFT             ',F10.2,' RPM'/
     *' OUTPUT SPEED OF GEAR SHAFT                  ',F10.2,' RPM'/
     *' DIRECTION OF INPUT SHAFT ROTATION           ',F8.3/
     *' INPUT TORQUE OF THE PINION SHAFT            ',F10.2,' IN-LB'/
     *' OUTPUT TORQUE OF THE GEAR SHAFT             ',F10.2,' IN-LB'/
     *' ANGLE BETWEEN INPUT AND OUTPUT SHAFT        ',F8.2,' DEG'/)
1202  FORMAT(
     *' NUMBER OF TEETH                             ',F8.2/
```

```
     *' PITCH ANGLE                                  ',F8.2,' DEG'/
     *' PITCH DIAMETER                               ',F8.2,' IN'/
     *' REFERENCE PITCH DIAMETER                     ',F8.3,' IN'/
     *' ADDENDUM                                     ',F8.3,' IN'/
     *' DEDENDUM                                     ',F8.3,' IN'/
     *'    FORCES ON A TOOTH IN THE MESH'//
     *' AXIAL FORCE                                  ',F9.1,' LB'/
     *' RADIAL FORCE                                 ',F9.1,' LB'/
     *' TANGENTIAL FORCE                             ',F9.1,' LB'/
     *' TOTAL FORCE                                  ',F9.1,' LB'/
     *' DYNAMIC CAPACITY IN FORCE                    ',F9.1,' LB'/)
1205  FORMAT( '     MOUNTING CHARACTERISTICS'//
     *' TYPE OF MOUNTING                             ',I5/
     *' DISTANCE A                                   ',F8.3/
     *' DISTANCE B                                   ',F8.3//
     *' AXIAL LOAD                                   ',F10.2,' LBS'/
     *' RADIAL LOAD                                  ',F10.2,' LBS'/
     *' TANGENTIAL LOAD                              ',F10.2,' LBS'/
     *' TOTAL EQUIVALENT FORCE                       ',F10.2,' LBS'/
     *' BASIC DYNAMIC CAPACITY OF BEARING #1         ',F10.1,' LBS'//
     *' AXIAL LOAD                                   ',F10.2,' LBS'/
     *' RADIAL LOAD                                  ',F10.2,' LBS'/
     *' TANGENTIAL LOAD                              ',F10.2,' LBS'/
     *' TOTAL EQUIVALENT FORCE                       ',F10.2,' LBS'/
     *' BASIC DYNAMIC CAPACITY OF BEARING #2         ',F10.1,' LBS'//
     *' DYNAMIC CAPACITY IN FORCE                    ',F9.1,' LB'/)
1209  FORMAT(///'    PINION CHARACTERISTICS AND MOUNTING     '//)
1210  FORMAT(///'    GEAR CHARACTERISTICS AND MOUNTING       '//)
      WRITE(1,1220)
      WRITE(1,1211)
      CALL DPLHE(D1(1),P1(1),L1(1),H1(1),E1(1))
      WRITE(1,1213)
      CALL DPLHE(D1(2),P1(2),L1(2),H1(2),E1(2))
      WRITE(1,1214)
      CALL DPLHE(D1(3),P1(3),L1(3),H1(3),E1(3))
      WRITE(1,1217)
      CALL DPLHE(D1(4),P1(4),L1(4),H1(4),E1(4))
      WRITE(1,1218)
      CALL DPLHE(D1(5),P1(5),L1(5),H1(5),E1(5))
      WRITE(1,1219)
      CALL DPLHE(D1(6),P1(6),L1(6),H1(6),E1(6))
1220  FORMAT(////
     *'          DYNAMIC CAPACITY AND LIFE IN TERMS OF'/
     *'                 OUTPUT TORQUE AND SPEED'//)
1211  FORMAT(' INPUT PINION'/)
```

```
1213  FORMAT(' INPUT BEARING #1'/)
1214  FORMAT(' INPUT BEARING #2'/)
1217  FORMAT(' OUTPUT GEAR'/)
1218  FORMAT(' OUTPUT BEARING #1'/)
1219  FORMAT(' OUTPUT BEARING #2'/)
      RETURN
      END
```

APPENDIX D

SYMBOLS

Variables

A	distance from gear to front bearing in inches
A_o	distance from apex to back of gear along pitch ray in inches
b	major axis contact length in inches
B	distance from gear to rear bearing in inches
B_c	back cone radius in inches
B_1	material constant in psi
C	dynamic capacity in pounds
D	gear diameter in inches or dynamic capacity in pound-inches
D_o	distance from apex to center of gear along pitch ray in inches
f	face width in inches
F	bearing force in pounds
l	life in million component cycles
L	life in million transmission cycles
m	gear ratio
n	number of planet gears
N	number of teeth
P_d	diametral pitch in 1.0/inches
R	gear radius in inches

S	probability of survival
T_i	input torque in pound inches
T_o	output torque in pound inches
W	gear load in pounds
Γ	cone angle in degrees
Λ	angle between input pinion shafts in degrees
Σ	shaft angle in degrees
$\Sigma\rho$	curvature sum in 1.0/inches
ϕ	pressure angle in degrees
ψ	spiral angle in degrees

Superscripts

e	Weibull slope
p	load-life factor

Subscripts

a	axial
b	bearing
bs	bearing in sun rotation units
g	gear
i	i'th unit
n	normal

ne	equivalent normal
p	pinion or planet
pr	planet meshing with ring
ps	planet meshing with sun
pt	planet tooth
r	ring or radial
R	combined radial
rl	left radial
rr	right radial
s	sun
t	tangential, thrust or tooth
T	combined tangential or transmission
tl	left tangential
tr	right tangential
1	first
2	second
3	third
10	90 percent reliability

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15. Supplementary Notes

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16. Abstract

A computer program which simulates life and reliability of helicopter transmissions is presented. The helicopter transmissions may be composed of spiral bevel gear units and planetary gear units - alone, in series or in parallel. The spiral bevel gear units may have either single or dual input pinions, which are identical. The planetary gear units may be stepped or unstepped and the number of planet gears carried by the planet arm may be varied. The reliability analysis used in the program is based on the Weibull distribution lives of the transmission components. The computer calculates the system lives and dynamic capacities of the transmission components and the transmission. The system life is defined as the life of the component or transmission at an output torque at which the probability of survival is 90 percent. The dynamic capacity of a component or transmission is defined as the output torque which can be applied for one million output shaft cycles for a probability of survival of 90 percent. A complete summary of the life and dynamic capacity results is produced by the program.

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